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Six experiments examined the problem-solving behavior of normal and mentally retarded (MR) children with a two-choice discrimination learning situation: the effects of stimulus similarity upon types of solutions utilized by MR children; the role of redundant cues in the discrimination learning of MR subjects with differing mental ages; the learning of reversal (RV), intradimensional (ID), and extradimensional (ED) shifts by kindergarten children and by MR's as a function of variation of the irrevelant shift dimension; and the hypothesis behavior in the discrimination learning situation of subjects at different developmental levels (data still being collected). Results indicated that stimulus similarity had no effect upon types of solutions adopted by MR children on discrimination problems. For MR subjects form cues predominated over color cues in the solving of discrimination problems, color-form compound cues were used, the negative compound was stronger than the positive compound, and strengths of cues did not change with overtraining. ID shifts were learned faster than ED shifts by MR children under all shift dimensions; ID and RV shifts were learned faster than ED shifts by kindergarten children only when the irrevelant shift dimension varied between trials. (Author/SN)

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February 1968

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
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OFFICE OF EDUCATION

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Donald J. Dickerson

February 1968

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Acknowledgments

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Joan Wagner was a graduate assistant on the project and co-authored two of the experiments. Other graduate students collaborating on different experiments were Thomas Wright, Reuben Altman, and Robert Ingalls. These individuals were invaluable as they engaged in the activities of planning and executing the research. Several colleagues also are due thanks. Dr. Joseph Campione, University of Washington, collaborated on one of the experiments. Dr. Laird Heal, George Peabody College for Teachers, was an efficient critic of research ideas. Dr. Betty House, Dr. Jerome Smith, and Dr. David Zeaman also had important things to say about research problems and problem-solving in general.

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INTRODUCTION

The research reported here is concerned with the problem-solving behavior of normal and mentally-retarded children. The experimental paradigm employed in all of the six experiments is that of two-choice, visual discrimination learning, a situation for the study of problem solving which is recommended by its marked simplicity. The different experiments have as their focus either (1) factors affecting problem-solving behavior or (2) the development of problem-solving behavior. The results of the experiments provide information which should contribute to the acquisition of an integrated body of knowledge about the basic learning and problem-solving processes in normal and mentally-retarded children. In a more practical vein, such knowledge also should aid in the construction of problem-solving situations which are conducive to rapid solution by individuals with specifiable characteristics.

General Methodology

The procedural techniques utilized in these experiments in general are very similar to those described by Zeaman and House (1963). The Wisconsin General Test Apparatus, modified for use with children, is the major piece of equipment. Figure 1 shows the major features of

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Insert Figure 1 about here

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this apparatus: a sliding tray displaying two stimuli, one of which is baited with candy or some other reward, and a one-way vision screen separating S and E. The E arranges the stimuli on the tray behind the screen, hides a reward under one, and slides the tray out to S. The S responds by lifting one of the stimuli. This completes one trial of a two-choice, visual discrimination learning problem. This procedure is repeated trial by trial until S responds consistently to the rewarded stimulus.

Theoretical Orientation

The experiments presented in the following pages, while focusing upon problem-solving behavior in general, have as their bases different theoretical orientations. Experiments 1 and 2 deal with the role that stimulus similarity plays in the determination of the type of solution adopted on discrimination problems by normal and mentally-retarded children. The theoretical basis for these experiments comes from contrasting views of the effective stimulus in discrimination learning (e.g., Gulliksen & Wolfle, 1938; Spence, 1936). Experiments 3, 4, and 5 are concerned with the establishment and transfer of

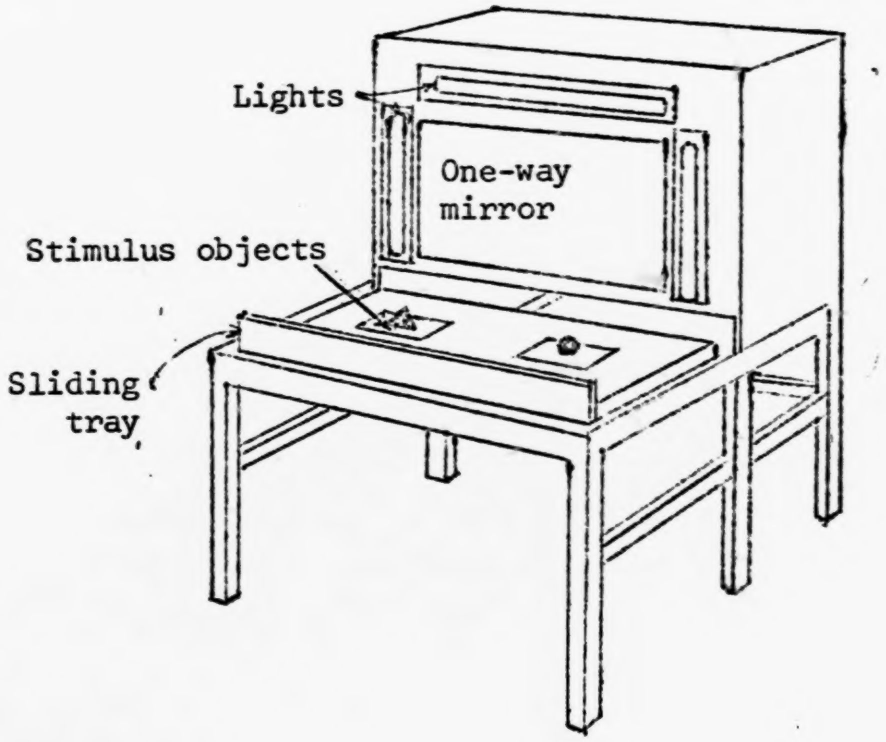
Lights
One-way mirror
Stimulus objects
Sliding tray

Figure 1. Discrimination learning apparatus.

mediating responses in discrimination learning. The orientation for these experiments comes from theories which view discrimination learning as involving a chain of two responses (Kendler & Kendler, 1962; Sutherland, 1964; Zeaman & House, 1963). Finally, Experiment 6, which is only partially completed at present, is a developmental study of hypothesis behavior in discrimination learning. This study has as its basis theoretical positions which view problem solving as a process of testing hypotheses and rejecting erroneous ones (e.g., Levine, 1963; Restle, 1962). Although the different experiments involve disparate approaches to the study of problem-solving behavior, all contribute to knowledge about this kind of behavior. Perhaps, with continued research of this type, the one best approach to the area will be determined.

Final Report Organization

Each of the major studies is reported in full in an integrated fashion. Experiments 1 and 2 are presented together since they deal with extremely similar questions. The major conclusions and implications emanating from the results of the experiments are presented at the end of this volume.

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Component, Configurational, and Compound Solutions in the Discrimination Learning of Mentally-Retarded Subjects

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Abstract

Two experiments were performed in order to assess the effects of stimulus similarity, both within-settings and between-settings, upon the type of solution adopted by mentally-retarded children. Three types of solutions were studied: component, configurational, and compound. A within-subjects experimental design was used such that each S received all treatments. The results of both experiments failed to show any differences in the solutions adopted as a function of stimulus similarity. Component solutions were used regardless of the manner in which stimulus similarity varied.

Component, Configurational, and Compound Solutions in the Discrimination Learning of Mentally-Retarded Subjects

Donald J. Dickerson and Thomas L. Wright

University of Connecticut

Theorists have varied widely with respect to the manner in which they have specified the stimulus and the response in discrimination learning. At one extreme is Spence (1936), who holds that Ss acquire approach tendencies to the components of the stimulus situation, e.g., approach Stimulus A and avoid Stimulus B. At the other extreme is the theoretical positions of Gulliksen and Wolfle (1938) which states that the total stimulus situation, or configuration, acts as a cue to which Ss learn directional responses, e.g., go left to Configuration 1 and go right to Configuration 2. Spence's formulation seems better suited for the explanation of data coming from the simultaneous discrimination problem in which two different stimuli are presented on each trial. One component is rewarded consistently and another component is nonrewarded consistently. The Gulliksen and Wolfle theory, on the other hand, appears more suitable for analyzing the successive discrimination problem in which the two stimuli presented on a specified trial are identical but are different from one trial to the next. The S may be rewarded for going left when Stimulus A is presented and for going right when Stimulus B is presented. (Examples of simultaneous and successive problems are shown in Figure 1.) However, each of the theories purports to account for the solution of both types of problems. According to the Gulliksen and Wolfle view, the simultaneous problem consists of successive presentations of two different configurations which are distinguished by different spatial relationships between the two components, i.e., A-B is one configuration and B-A is another configuration. In order to explain the solution of the successive problem, Spence (1952) required an additional assumption: namely, that approach responses are learned to cue-position compounds if no component is rewarded consistently. Thus, S may learn in the successive problem to approach A-left and B-right and to avoid A-right and B-left. Spence further states that the component solution is more simple than the compound solution and, therefore, that the simultaneous problem should be learned more quickly than the successive problem. The opposite prediction can be generated by Gulliksen and Wolfle since the two configurations involved in the successive problem are more distinct than the ones involved in the simultaneous problem. These predictions have been tested in a number

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Insert Figure 1 about here

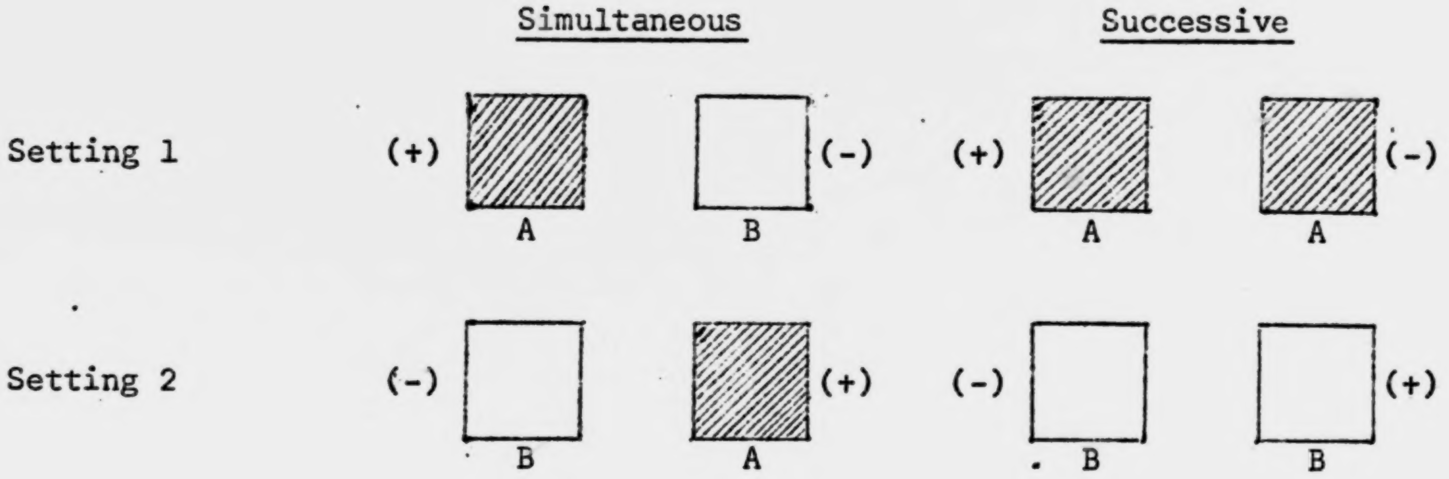
Simultaneous
Successive
Setting 1
(+)
A
B
(-)
(+)
A
A
(-)
Setting 2
(-)
B
A
(+)
(-)
B
B
(+)

Figure 1. Simultaneous and successive discrimination problems.

of studies (e.g., Weise & Bitterman, 1951; Spence, 1952; Bitterman & Wodinsky, 1953), but the results have been inconclusive. Other research suggests that the type of solution adopted by Ss in learning the two types of problems is a function of certain stimulus factors (e.g., McCaslin, 1954; Wodinsky, Varley, & Bitterman, 1954; Bitterman, Tyler, & Elam, 1955).

Teas and Bitterman (1952) introduced a paradigm which seems better suited for assessing the types of solutions adopted by Ss. The essentials of the situation are illustrated in Figure 1. The S first is given training on the two-setting problem. This problem can be learned by utilizing either component (approach A and D and avoid B and C), compound (approach A-left and D-right and avoid B-right and C-left), or configurational (go left to A-B and go right to C-D) solutions. After training on the two-setting problem is completed, S then is given training on the four-setting problem. This transfer problem provides a basis for inferring the type of solution adopted in the two-setting problem. Here, the two original settings (Settings 1 and 2) are presented along with two new settings involving the same stimuli but with the spatial positions of the stimuli reversed (Settings 3 and 4). Performance on the first two trials with the new settings indexes the type of solution. The Ss who have learned component solutions should approach A and D in the new positions. The Ss who have learned only compound solutions should respond inconsistently on these two trials since the cue-position compounds of original learning do not appear. The Ss who have learned to go left to Setting 1 and right to Setting 2, the configurational solution, should go left to Setting 3 and right to Setting 4. This latter prediction assumes, of course, that the change in position of the stimuli does not change the "configuration" appreciably. For the remaining trials of the transfer problem, all four settings are presented and, as indicated in Figure 1, some Ss are rewarded for responding to components and others are rewarded for responding to configurations. The relative ease of learning the component and configurational four-setting problems should indicate further the type of solution transferred from original learning of the two-setting problem.

Insert Figure 2 about here

Stimulus similarity may play an important role in the determination of the type of solution adopted in the two-setting problem. Inspection of Figure 2 shows that with an increase in the similarity of A and D and of B and C, the two-setting approaches a simple simultaneous discrimination. Likewise, as A is made more similar to B, and C is made more similar to D, the problem comes closer to a standard successive discrimination. Thus, one might expect the type of solution adopted on the two-setting problem to be affected by the

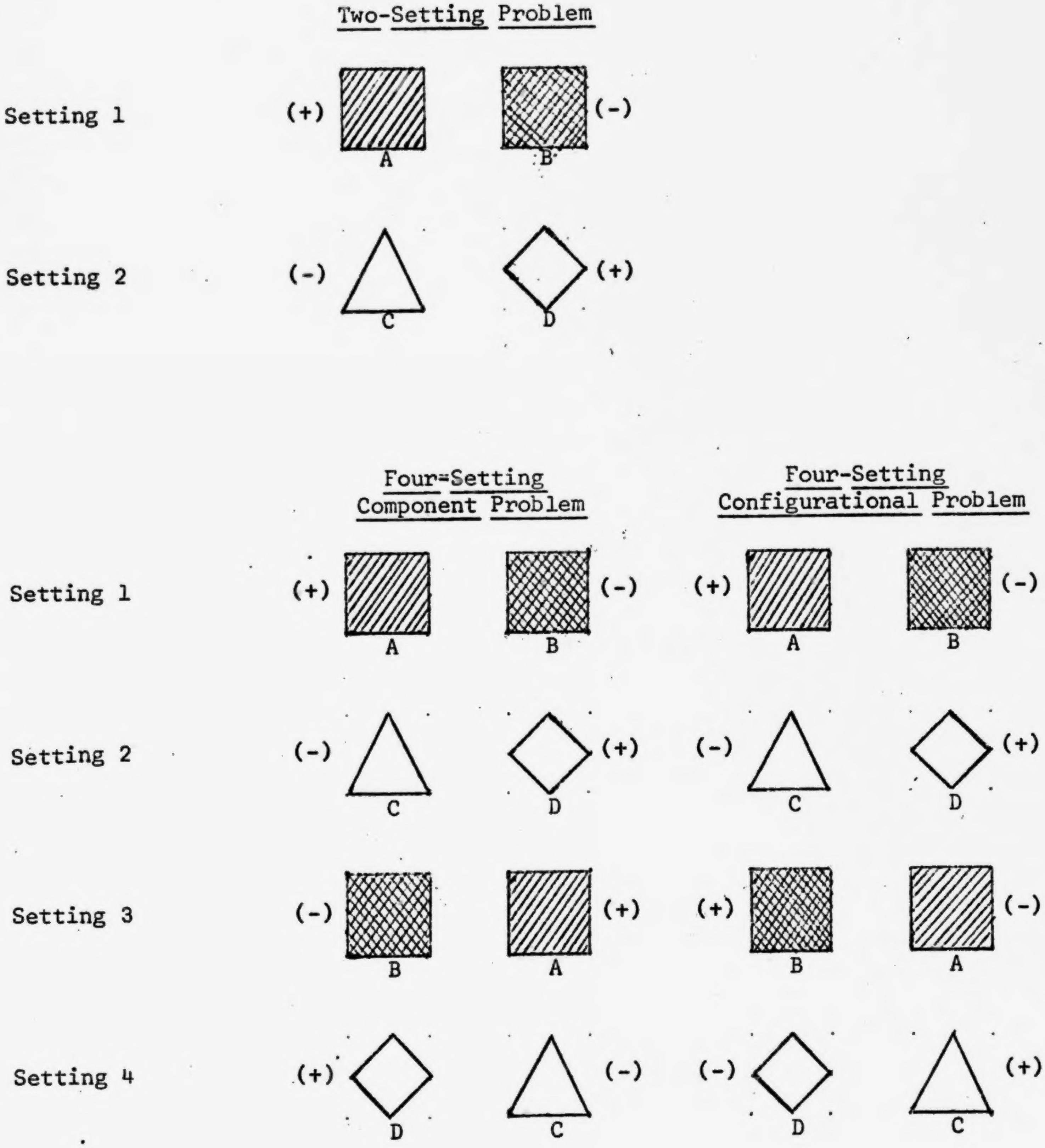
Two-Setting Problem
Setting 1
(+)
A
B
(-)
Setting 2
(-)
C
D
(+)
Four=Setting Component Problem
Four-Setting Configurational Problem
Setting 1
(+)
A
B
(-)
(+)
A
B
(-)
Setting 2
(-)
C
D
(+)
(-)
C
D
(+)
Setting 3
(-)
B
A
(+)
(+)
B
A
(-)
Setting 4
(+)
D
C
(-)
(-)
D
C
(+)

Figure 2. Schematic representation of the paradigm introduced by Teas and Bitterman.

manipulation of within-setting and between-setting stimulus differences. Evidence is available which lends support to this expectation.

In a study employing retarded children as Ss, Shepp (1963) varied stimulus similarity within and between settings by manipulating the number and kind of relevant stimulus dimensions. Table 1 shows the most important features of the design of Shepp's experiment. In Table 1 the letters F and C refer to the dimensions of form and color, respectively, and the different subscripts (1, 2, 3, & 4) refer to particular values along these dimensions. One group (2DV) had two dimensions variable within Settings 1 and 2, with the same dimensions varying in both settings. The other two groups had only one dimension variable within each setting. Group SDV had the same dimension variable in both settings, while for Group DDV different dimensions varied in Settings 1 and 2. When the Ss in these groups were given transfer trials on Settings 3 and 4, it was found that Group 2DV was

Insert Table 1 about here

responding primarily to components, that Group SDV was responding primarily to compounds, and that Group DDV was responding primarily to configurations. Thus, it appears that component solutions are adopted when the stimuli within settings are very distinctive. When the stimuli within settings are made similar, however, compound or configurational solutions are adopted. Moreover, compound solutions seem to result when Settings 1 and 2 vary with respect to the same stimulus dimension, and configurational solutions seem to result when Settings 1 and 2 vary along different dimensions.

Shepp's findings are consistent with the results of earlier experiments. Teas and Bitterman (1952), using a situation analogous to the DDV condition, found a preponderance of configurational solutions in rats. In addition, White and Spiker (1960) have shown that preschool children respond to components in a situation similar to the SDV condition when stimuli within settings are distinctive. However, when stimuli within settings are very similar, preschool children respond to cue-position compounds.

The present experiments were directed at further delineation of the role of stimulus similarity in the determination of the manner in which discrimination problems are solved. Experiment 1 was an attempt to replicate the main findings of Shepp's study while employing an experimental design in which each S received all treatments. Experiment 2 dealt with the effects on type of solution of varying between-setting stimulus differences with within-setting differences held constant.

Table 1

Two-Setting Problems Involved in Shepp's Experiment

Group	Setting	left	right	Rewarded Position
2DV	1	C_1F_1	C_2F_2	Left
	2	C_3F_3	C_4F_4	Right
SDV	1	C_1F_1	C_2F_1	Left
	2	C_3F_2	C_4F_2	Right
DDV	1	C_1F_1	C_2F_1	Left
	2	C_3F_2	C_3F_3	Right

Experiment 1

Method

Subjects--The Ss were 12 mentally-retarded residents of the Mansfield State Training School. The mental ages of these Ss ranged from 3 to 5 years, and the chronological ages ranged from 14 to 20 years. Ten of the 12 Ss who began the experiment finished it. Two Ss were discontinued in the experiment due to failure to complete pretraining.

Apparatus--A Wisconsin General Test Apparatus, modified for use with children, was employed. Components of this apparatus were (a) a sliding tray containing two 3-in. food cups centered 12 in. apart and (b) a one-way vision screen separating E from S (see Bijou & Baer, 1960, for a more detailed description of the apparatus). There were 64 different stimulus objects, consisting of all combinations of 8 colors: red, green, black, yellow, brown, pink, blue, and white; and 8 forms: square, circle, cross, diamond, triangle, T, Z, and I. The forms were cut from 1/4-in. Masonite and were mounted vertically on 4 x 4 in. gray Masonite bases. Maximum height and width of each stimulus was 2 in. M & M candies served as rewards during the experiment.

Procedure--Prior to beginning the experiment, each S was given a series of pretraining problems. These problems were two-setting problems of the DDV variety. Twenty-four trials were given each day during pretraining, and Ss were trained on a particular problem until they reached a criterion of 20/24 correct in a single daily session. After reaching this criterion on the first problem, Ss were given additional DDV problems until they reached the learning criterion on a new DDV problem in their first session with it, whereupon pretraining was terminated. During the experiment proper, which was begun on the day following the completion of pretraining, each S was trained to the 20/24 criterion on a series of 24 two-setting problems. Included in the series were 8 2DV, 8 DDV, and 8 SDV problems. Two test trials were given with Settings 3 and 4 of each problem immediately following criterion performance. Both stimuli were "baited" with candy on the test trials and, therefore, S's first response was rewarded. The order in which the different problems were presented was determined randomly with the restriction that no two consecutive problems were of the same type. Throughout the experiment, the color-form stimuli involved in the two-setting problems were determined randomly, although no two consecutive problems contained the same color or form components. A correction procedure was employed on all trials except test trials.

Results

The criterion measure was the total number of component responses made on test trials under each of the three experimental conditions. Since, for a given S, there were 8 problems of each type and two test trials per problem, the maximum score which could be obtained was 16.

Thus, a score of 16 (100%) would indicate the use of component solutions, a score of 0 (0%) would indicate the use of configurational solutions, and a score of 8 (50%) would suggest the use of compound solutions.

The mean number of component responses for each of the three types of problems is shown in Figure 3. It appears that component solutions predominate regardless of within-setting and between-setting differences in stimulus similarity. An analysis of variance of the

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Insert Figure 3 about here

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scores showed that there was no significant differences among the three types of problems, $F(2, 18) = 1.93$, $.20>P>.10$.

The binomial test was used in order to determine for each S whether the number of component responses on test trials with each type of problem was greater or less than the number expected by chance, i.e., 8 component responses. It was determined that the probability of S making 13 or more component responses on a given type of problem was equal to .022 (two-tailed). Using 13 or more component responses as the criterion for "above chance" responding it was found that 8 Ss (of 10) were above chance on the 2DV problems, 6 Ss were above chance on the SDV problems, and 6 Ss were above chance on the DDV problems. Thus, more than half of the Ss showed "strong" component responding on each of the three types of problems.

The results of this experiment do not reproduce those found by Shepp (1963). Component solutions were adopted in the present study regardless of variation in stimulus similarity.

Experiment 2

Method

Subjects--The Ss were 12 mentally-retarded residents of the Mansfield State Training School. The characteristics of these Ss were the same as those for the Ss of Experiment 1. Ten Ss finished Experiment 2 as two Ss failed to complete pretraining.

Apparatus--The apparatus was the same as that employed in Experiment 1.

Procedure--The within-subjects type of experimental design again was employed. The general procedure of the experiment was identical to that of Experiment 1, with the exception that the problems were different.

Table 2 shows the three types of problems involved. The letters F, C, and S refer to the dimensions of form, color, and size, respect-

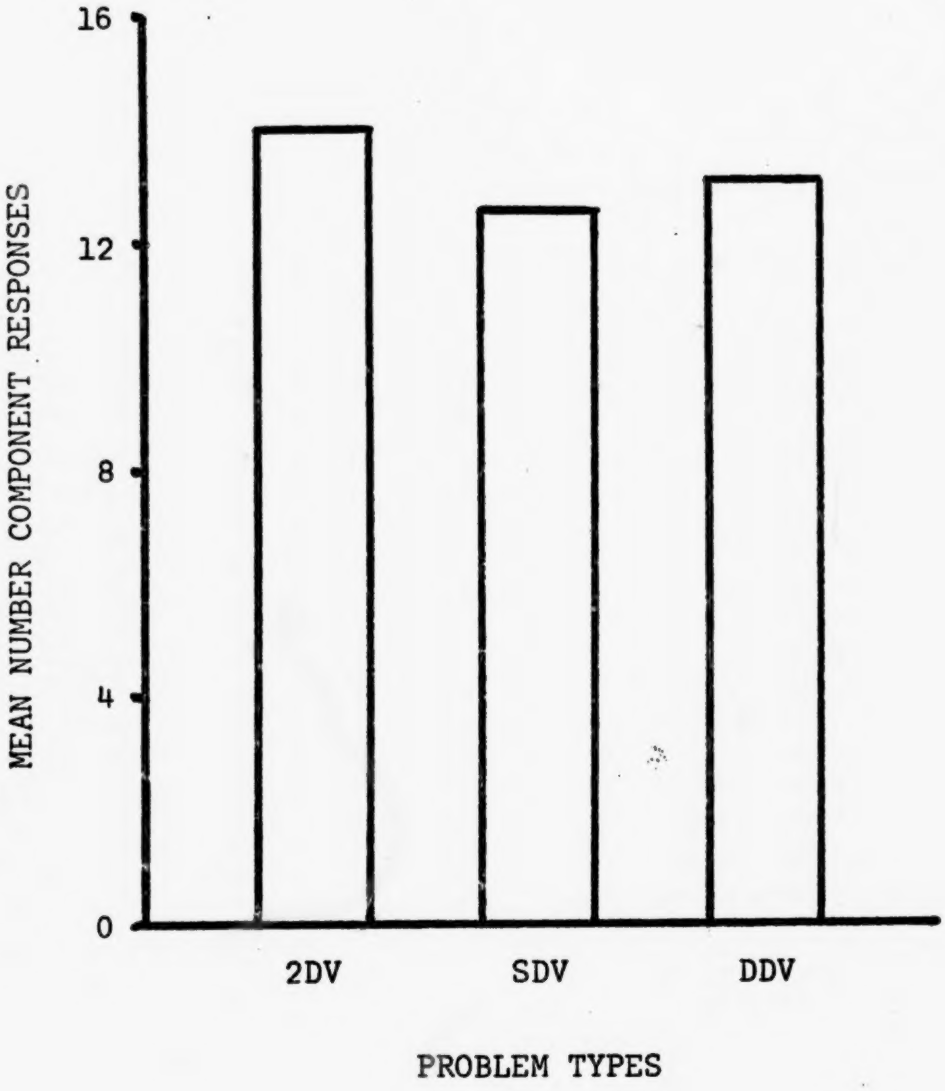

Figure 3. Mean number component responses on test trials for the three types of problems of Experiment 1.

ively, and the subscripts again designate different values along these dimensions. All three conditions were variations of Shepp's SDV problem in that only one dimension was variable within each setting and the same dimension was variable within settings 1 and 2. In the 1V problems, only one dimension was variable between settings, and this dimension was the same one which was variable within settings. The 2V problems had two dimensions variable between settings, and the 3V problems had three dimensions variable between settings.

Insert Table 2 about here

Eight problems of each type were learned by each S with 2 test trials following each problem. Pretraining was given with problems of the 3V type.

Results

The mean number of component responses for each of the three problem types is shown in Figure 4. Component responses apparently were the predominant type made on all problems. An analysis of variance showed no significant differences among the three types of problems. In addition, the binomial test showed that the number of component responses was above chance for 8 Ss on each of the three types of problems. Between-setting differences in stimulus similarity, therefore, does not seem to influence the type of solution adopted. Component solutions seem to be the rule regardless of the magnitude of such differences.

Insert Figure 4 about here

Discussion

The results of the two present experiments are not consonant with the results of other experiments which indicate that stimulus similarity influences the way in which discrimination problems are solved (Mc Caslin, 1954; Shepp, 1963; Teas & Bitterman, 1952; White & Spiker, 1960). There are two conclusions which are possible: (1) the results of preceding experiments notwithstanding, stimulus similarity does not affect the type of solution adopted, or (2) for some reason the present experiments did not recover the effects which stimulus similarity has upon the type of solution adopted. The latter conclusion is preferred, of course, solely on numerical grounds. In addition, the experimental procedure was different from those used in other studies. A within-subjects design in which each S received every treatment was used here. In previous studies, between-subjects designs in which a given S received only one treatment has been the rule. It seems likely that when S learns a series of problems he adopts one consistent

Table 2

Two-Setting Problems Involved in Experiment II

Problem	Setting	left	right	Rewarded Position
1V	1	$C_1F_1S_1$	$C_2F_1S_1$	Left
	2	$C_3F_1S_1$	$C_4F_1S_1$	Right
2V	1	$C_1F_1S_1$	$C_2F_1S_1$	Left
	2	$C_3F_2S_1$	$C_4F_2S_1$	Right
3V	1	$C_1F_1S_1$	$C_2F_1S_1$	Left
	2	$C_3F_2S_2$	$C_4F_2S_2$	Right

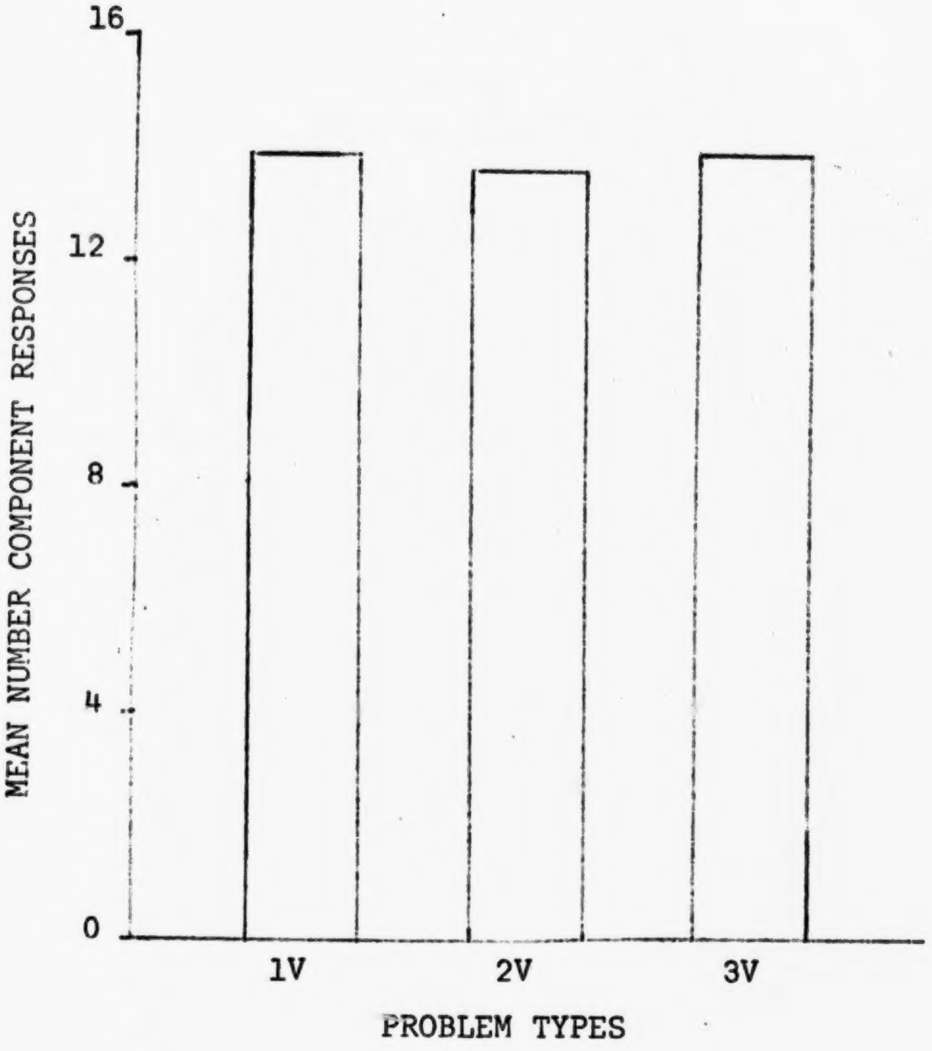

Figure 4. Mean number component responses on test trials for the three types of problems of Experiment 2.

solution which is used on all problems. The results of the present experiments indicate that a component solution is the one adopted.

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Attention to Redundant Cues
in the Discrimination Learning of Retardates

Donald J. Dickerson and Reuben Altman

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Abstract

Retarded Ss at two different MA levels (MA 3-5 and MA 6-8) first learned to a criterion a two-choice, color-form discrimination problem with both dimensions relevant, and then received 144 overtraining trials on the same problem. Transfer trials were interspersed among the regular overtraining trials. These test trials were designed to yield information (a) about the nature of the cues used by S in learning the problem and (b) about the manner in which responses to these cues changed during overtraining. The results yielded the following findings: (a) Learning was faster in the MA 6-8 Group than in the MA 3-5 Group, while overtraining and transfer performance were similar for the two groups. (b) A larger role was played in problem solution by form cues than by color cues, although both were important. (c) Color-form compound cues also contributed to overall performance. (d) Avoidance of the negative compound was stronger than approach to the positive compound. (e) The strengths of all of these cues did not change during the course of overtraining.

Attention to Redundant Cues in the Discrimination Learning of Retardates

Donald J. Dickerson and Reuben Altman

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The results of recent transfer-of-discrimination experiments have given rise to theories which assume that discrimination learning involves the acquisition of a chain of two responses (Kendler & Kendler, 1962, Lovejoy, 1965, Sutherland, 1964, Wyckoff, 1952, Zeaman & House, 1963). While these "chaining" theories are very similar in many respects, there are certain fundamental differences among them. A specific difference between two of these theories will be considered here. The theories of Zeaman and House (1963) and Sutherland (1964) both assume that in order to solve a discrimination problem S first must learn to attend to the relevant stimulus dimension and then to approach the positive cue along that dimension. However, the properties of the attentional response are different for the two theories. The most general form of the theory proposed by Zeaman and House makes the assumption that on a given trial S attends to only one stimulus dimension. Therefore, S learns something about the cues along the dimension to which he attends but nothing about the cues on other dimensions. Sutherland, on the other hand, does not make attending to a dimension an all-or-none process. Instead, he views attentional responses as differing in their strengths. The S learns most about the cues along the dimension to which he attends the most strongly. However, S also may learn about the cues along other dimensions, providing the strength of the attentional response to these dimensions is above some critical amount.

The foregoing theoretical positions, if they have been interpreted correctly, can predict different results in certain experimental situations. The present experiment provides such a situation. In this experiment, mentally-retarded Ss first are trained to a criterion and then are given overtraining on a discrimination problem in which two dimensions are relevant. For example, in one such situation S learns a problem in which a black square is the positive stimulus object and a white circle is the negative stimulus object. Both form and color are relevant dimensions and S can solve the problem by attending to either dimension. Let's suppose that in this situation the attentional response to one of the relevant dimensions is stronger than the attentional response to the other relevant dimension. (Data are available which indicate that Ss initially are prone to attend to only one of the variable dimensions in a problem.) The Zeaman and House formulation predicts that S will be attending to the strong dimension at criterion and, since attending to one dimension precludes attending to other dimensions, S will learn nothing during overtraining about the cues on the other, redundant, relevant dimension. Sutherland's theory also predicts that at criterion S's performance will be controlled primarily by the cues along the strong dimension. However, attending to one dimension does not mean that S is learning nothing about the cues along the other relevant dimension. Therefore, as overtraining progresses one might expect that S will learn more and more about these redundant cues. In the present experiment, the amount learned about the cues on the two different dimensions was assessed by means of transfer tests which were administered during overtraining. This transfer-test procedure first was employed by Sutherland and Holgate (1966) in an experiment with rat Ss. The exact nature of the transfer tests will be outlined subsequently.

Another aspect of the present experiment was that the amount learned about the cues on the two relevant dimensions was assessed for two groups of retarded Ss which differed in mental age (MA). Supposing that S does learn more and more as overtraining progresses about the cues on the weak dimension (i.e., Sutherland's prediction), one might expect MA to be related directly to the rate at which the learning occurs. The more adaptable individual (high MA) might be expected to learn relatively more about cues which are relevant but not essential for a high performance level. However, Crane and Ross (1967), as well as other writers, have argued that the opposite situation pertains. The more adaptive behavior involves not attending to redundant cues. Thus, rate of learning about the cues on the weak dimension and MA would be inversely related from this viewpoint.

One final point about the present experiment now should be made. Consider, once again, the discrimination problem involving the black square and the white circle. In discussing the learning of this problem, only simple component solutions were considered. The S was assumed either to attend to form and approach square or to attend to color and approach black. A more complicated solution is possible according to the Zeaman and House theory. The S might learn to approach not simple components like square or black, but the black square--that is, the combination of two aspects as a unitary pattern, different from either of the constituent components. House and Zeaman (1963) term this a compound solution. Their theory allows for such solutions by assuming that S may learn to attend to compound dimensions. The compound dimension formed by the combination of the color and form components is relevant in the aforementioned problem. Transfer tests also were designed to cast light upon S's use of compound cues in this experiment.

Method

Subjects--Two groups of 12 mentally-retarded Ss from a residential institution initially were selected. The IQs ranged from 30 to 50 in both groups. One group had MAs in the range from 6.0 yrs. to 8.0 yrs. The second group had MAs in the range from 3.0 yrs. to 5.0 yrs. A total of four Ss were dropped for highly destructive behavior in the experimental setting. Three Ss were dropped from the MA 3-5 Group: one for failing the pretraining problem and two for failing the training problem. Descriptive statistics for the Ss participating in the experiment are contained in Table 1.

Insert Table 1 about here

Table 1

Descriptive Statistics on IQ, MA, and CA,

for the Two Groups

Group	N	Measure	IQ	MA (in years)	CA (in years)
MA 6 - 8	11	Mean	42.18	7.01	21.76
		SD	4.10	0.58	2.70
MA 3 - 5	9	Mean	38.56	4.07	11.97
		SD	5.08	0.68	1.31

Apparatus--A modified version of the Wisconsin General Test Apparatus was used. The S and E sat facing each other with a one-way vision screen interposed. A 30 x 12 inch stimulus tray containing two circular food wells, 2 inches in diameter and separated by 12 inches from center to center, could be directly presented in front of S by pushing it under a space beneath the one-way screen. The entire apparatus, excepting the one-way screen, was painted gray.

Stimuli were three-dimensional objects differing in form (triangle, T, cross, circle, and square) and color (red, green, yellow, black, and white). All stimuli were two inches high and were mounted on gray squares, 3 x 3 x 1/4 inches.

General Procedure--Each S was brought individually into the experimental room where he was told that he was going to play the "candy game." Pretraining was begun immediately; the reward for a correct response being an M & M candy. A correction procedure was used throughout. In addition to the candy reward, correct responses were verbally rewarded with "good" and incorrect responses punished with "no." The position of the correct stimulus was varied according to a Gellermann series.

Pretraining--Before starting the experiment, S was pretrained on a discrimination problem involving a pair of "junk" stimuli (i.e., stimuli varying multidimensionally in size, shape, color, texture, etc.). The two stimuli were selected at random from a large collection of such stimuli. Each S then was run for 24 trials per day until reaching a criterion of 20 correct responses within a single daily session. All Ss not reaching criterion after a total of 6 days (144 trials) were dropped from the experiment. Only one S, an S in the MA 3-5 Group, failed pretraining.

Training--After pretraining, S learned a two-choice, object discrimination problem in which the two discriminative stimuli differed simultaneously in both color and form (e.g., a black square versus a white circle). Therefore, the color and form dimensions both were relevant to problem solution. Also relevant was the compound dimension formed by the combination of the color and form cues. The specific stimuli involved in a given problem were selected at random from those available. The positive stimulus in each problem also was designated randomly. All Ss were run for 24 trials per day until reaching a criterion of 20 correct responses in a single daily session. Any S not reaching criterion in 6 days (144 trials) was dropped from the experiment. Two Ss failed to attain criterion. Both were in the MA 3-5 Group.

Overtraining and Transfer Tests--Six days of overtraining were administered on the same problem. Here, S received 36 trials per day. However, only 24 of these trials actually were overtraining trials (i.e., trials identical to those administered during training). The remaining 12 daily trials were test trials which were designed to yield information (a) about the nature of the cues used by S in learning the problem and (b) about the manner in which responses to these cues changed during the course of overtraining.

Figure 1 gives an example of a discrimination problem and the four different transfer tests for this problem. The training problem involves a discrimination between a black square and a white circle with

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Insert Figure 1 about here

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the former as the positive stimulus. On a given transfer test, the cues on one of the relevant dimensions remain unchanged while the cues along the other dimension are made constant at one of the training values. Thus, on tests of the C_1 and C_2 variety only the color cues (black and white) are available, while on tests of the F_1 and F_2 variety only the form cues (square and circle) are available. Therefore, if S is attending to color and not attending to form, he should respond in a manner consistent with the training problem (i.e., to the black stimulus) on the C_1 and C_2 tests and in a manner inconsistent with the training problem (i.e., to the square only 50 per cent of the time) on the F_1 and F_2 tests.

The transfer tests also should yield information about responses to compounds. On the C_1 and F_1 tests, the positive training compound (black square) is retained and is paired with a new negative compound. On the C_2 and F_2 tests the negative training compound (white circle) is retained and is paired with a new positive compound. Thus, if S responds in a manner consistent with the training discrimination on the C_1 and F_1 tests more frequently than on the C_2 and F_2 tests, it will indicate (a) that attention to the color-form compound dimension is involved in learning and (b) that the tendency to approach the positive compound is greater than the tendency to avoid the negative compound.

On a given day during overtraining, S received 8 trials on the training problem, followed by one trial on each of the four tests (C_1, C_2, F_1, and F_2). This sequence of 12 trials was repeated twice for the total of 36 trials administered in a single daily session. The sequence of test trials within each series of four was randomly determined. A piece of candy was placed under both stimuli on test trials; thus, any response made by S on these trials was rewarded immediately.

Results and Discussion

Original Learning and Overtraining. Forward learning curves are presented in Figure 2 which portray the course of original learning and overtraining for the two groups. In constructing the curves for original learning, postcriterion performance was assumed to be at the same level that it was on the criterion day. Learning evidently is slower in the MA 3-5 Group, while performance during overtraining is comparable for the two groups. The first generalization is substantiated

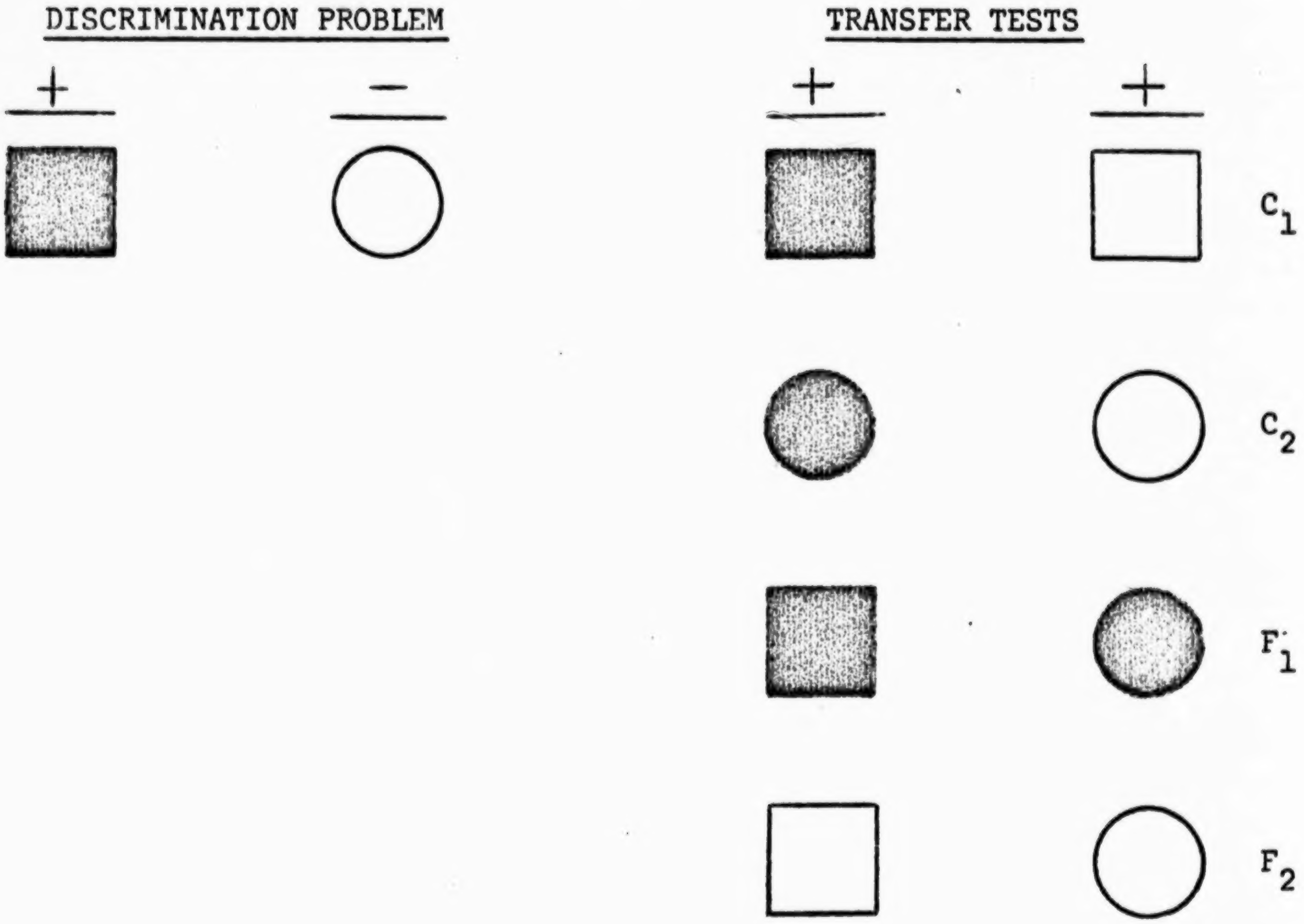
DISCRIMINATION PROBLEM
+
−
TRANSFER TESTS
+
+
C1
C2
F1
F2

Figure 1. Example of a discrimination problem and the four transfer tests for the problem.

further by errors-to-criterion scores. The MA 3-5 Group had 13.67 mean errors to criterion and the MA 6-8 Group had 3.73 mean errors to criterion.

Insert Figure 2 about here

Transfer Tests. A response on a given test trial was scored as either consistent or inconsistent with problem solution. A total of 72 test trials were administered to S. Since there were four transfer tests (C_1, C_2, F_1, and F_2), S received 18 trials on each test, 3 trials per day for 6 days. The criterion measure was the number of consistent responses on a given transfer test.

The criterion scores were submitted to two different analyses of variance. The first analysis was a 2 x 2 x 2 design with dimension (form vs. color) and compound (positive vs. negative) as within-subjects factors and MA as a between-subjects factor. For the second analysis, the distinction between color and form dimensions was abandoned and a distinction was made between S's strong and weak dimensions; the strong dimension being the one to which S made the larger number of consistent responses. This analysis also was a 2 x 2 x 2 design. Dimension (strong vs. weak) and compound (positive vs. negative) were within-subjects factors, while MA was a between-subjects factor. Both analyses fail to treat days as a factor since transfer performance did not change over days. This fact is evidenced by the graphs which shortly are to be presented.

The results of the two analyses are summarized in Tables 2 and 3. Note that the results of the analyses are the same except for the effect of dimension and the interactions involving the dimension factor. This situation pertains since the same data were involved in both analyses and only partitioned in a different manner.

Insert Tables 2 & 3 about here

Effects of MA. There was no significant effect of MA. The Ss in the MA 3-5 Group responded on the tests in a manner consistent with problem solution as frequently as the MA 6-8 Group. Figure 3 shows the performance over days of the two groups on all tests combined. Interactions involving the MA factor will be discussed subsequently.

Insert Figure 3 about here

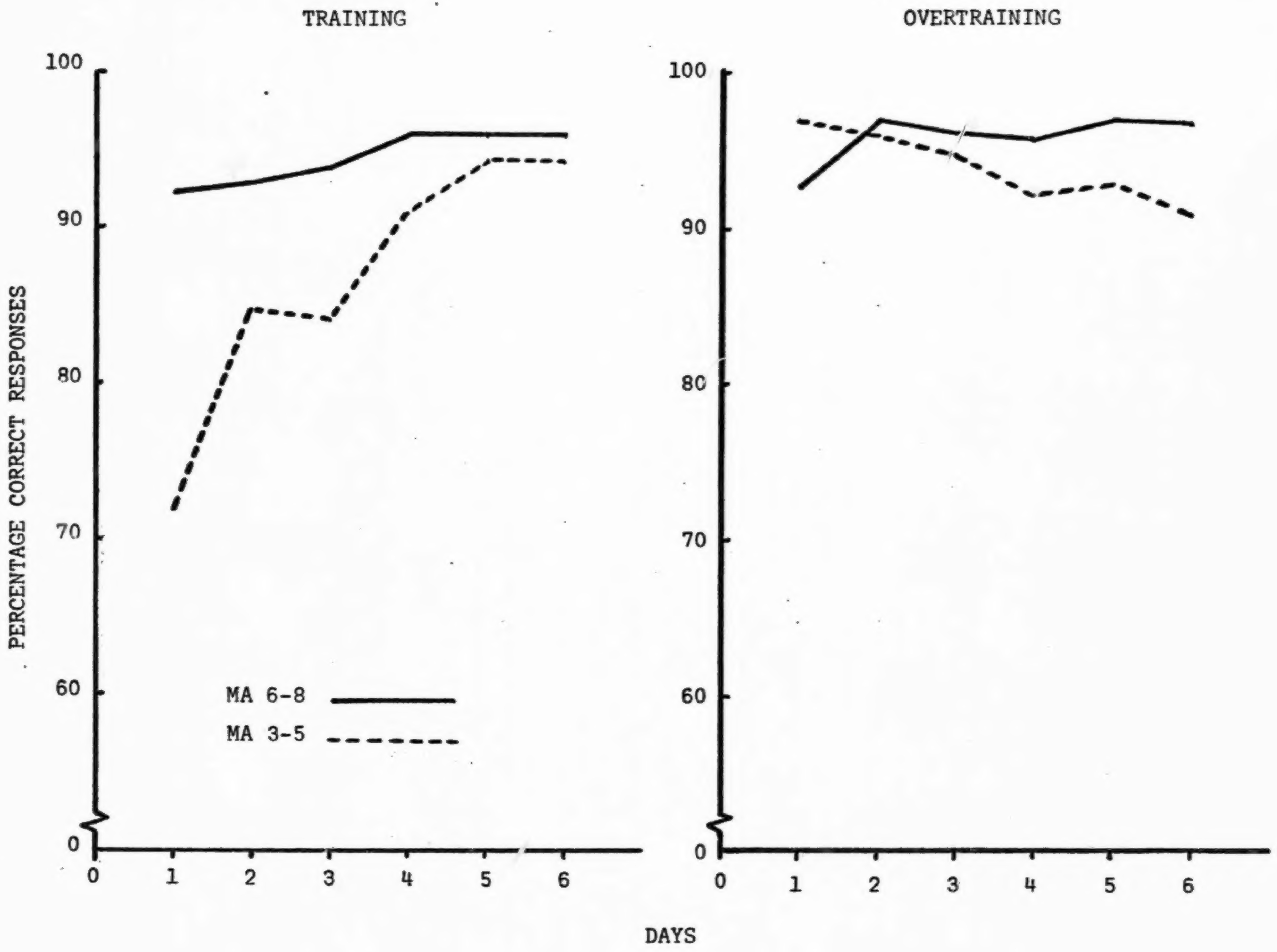

Figure 2. Forward learning curves showing original training and overtraining for the two MA groups.

Table 2

Summary of Analysis of Variance of the Transfer Data

(Color vs. Form)

Source	df	MS	F
Between-Ss	19		
MA	1	11.00	0.54
error (between)	18	20.39	
Within-Ss	60		
Dimension (D)	1	131.00	11.79*
Compound (C)	1	46.00	6.90**
DxC	1	16.00	3.47***
DxMA	1	7.00	0.63
CxMA	1	22.00	3.30***
DxCxMA	1	1.00	0.22
DxCxMAxS	54	7.46	
DxMAxS	18	11.11	
CxMAxS	18	6.67	
DxCxS	18	4.61	
Total	79		

*$p<.005$
**$p<.025$
***$.05<p<.10$

Table 3

Summary of Analysis of Variance of Transfer Data

(Weak vs. Strong)

Source	df	MS	F
Between-Ss	19		
MA	1	11.00	0.54
error (between)	18	20.39	
Within-Ss	60		
Dimension (D)	1	208.00	28.15*
Compound (C)	1	46.00	6.90**
DxC	1	17.00	3.87***
DxMA	1	2.00	0.27
CxMA	1	22.00	3.30***
DxCxMA	1	1.00	0.23
DxCxMAxS	54	6.11	
DxMAxS	18	7.39	
CxMAxS	18	6.67	
DxCxS	18	4.28	
Total	79		

*$p<.001$
**$p<.025$
***$.05<p<.10$

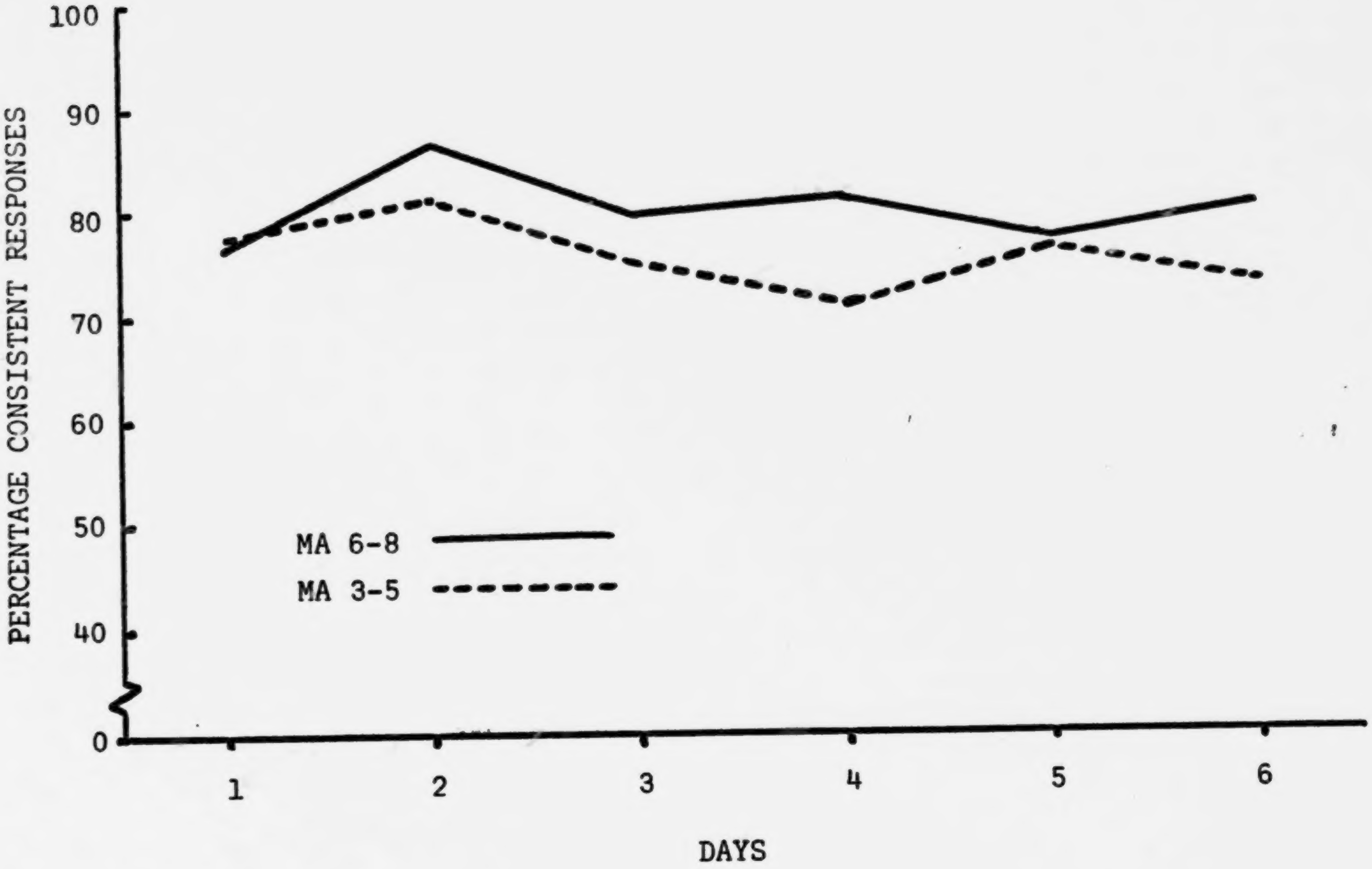

Figure 3. Transfer test performance of the two MA groups.

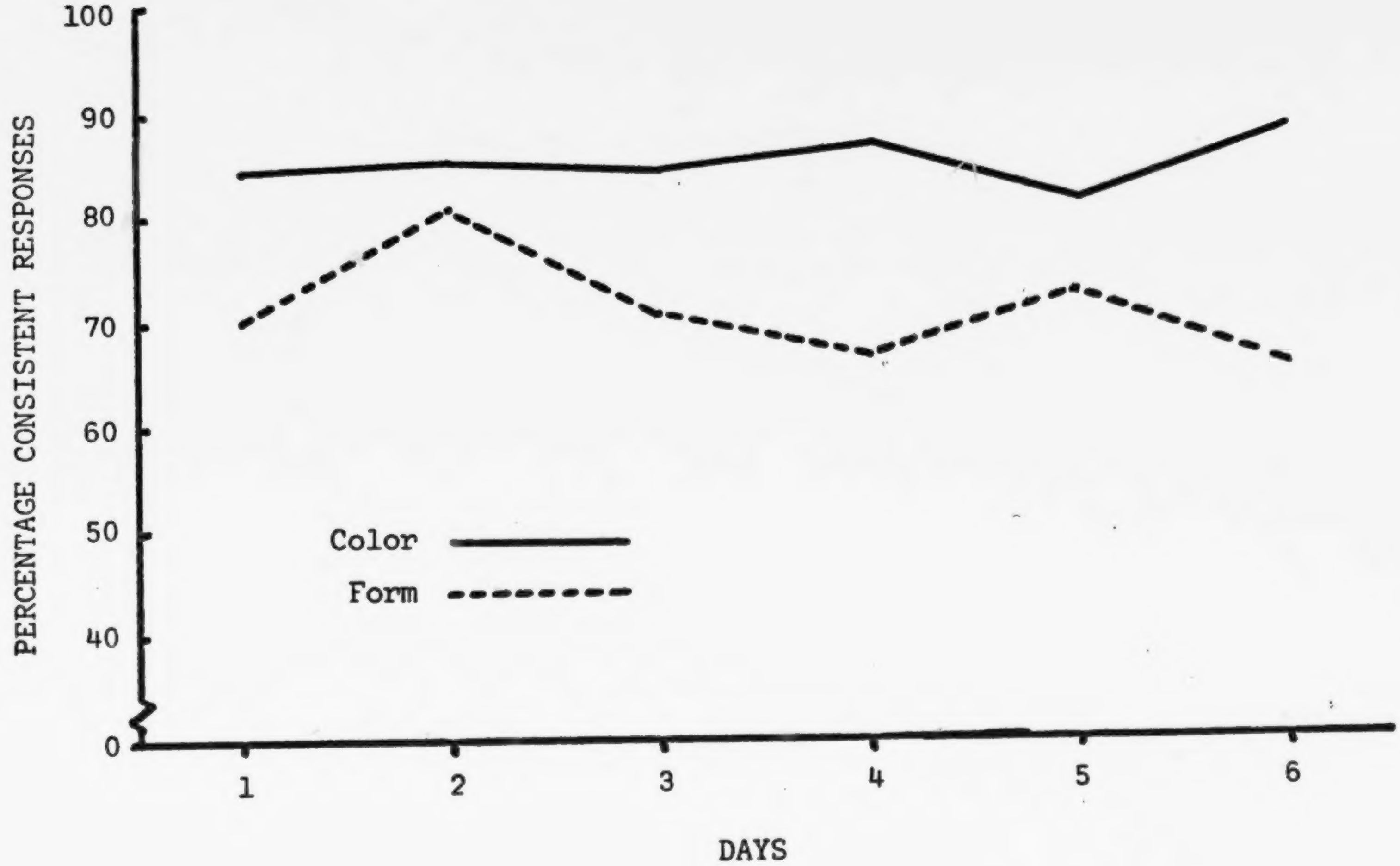

Figure 4. Performance of all Ss on the color and form transfer tests.

Dimension Dominance. The analysis summarized in Table 2 yielded a significant dimension main effect. Figure 4 shows the performance of all Ss on the color (C_1 and C_2) and form (F_1 and F_2) tests. Performance consistently was better on form tests than on color tests. This finding suggests that the Ss tended to solve the problems by attending to the form dimension more frequently than by attending to the color dimension. Scrutiny of the scores of individual Ss showed that only 3 Ss, 2 in the MA 6-8 Group and 1 in the MA 3-5 Group, performed better on color than on form tests. The dominance of form over color is not surprising. It has been found repeatedly (e.g., Zeaman & House, 1963) that retarded children in the MA range employed here solve form problems more rapidly than they solve color problems.

Insert Figure 4 about here

Use of Redundant Cues. The major hypothesis of this experiment was that S initially would solve the training problem by attending to a single relevant dimension. As overtraining progressed, S was expected to learn more and more about the cues along the other dimension. In addition, it was expected that the Ss in the MA 3-5 Group would learn about the redundant cues more slowly than would the Ss in the MA 6-8 Group.

Figure 5 presents graphically the results of transfer tests which bear upon the foregoing hypotheses. Shown here is the transfer performance of the two MA groups on their strong and weak dimensions. Performance on the strong dimension naturally is high (around 90% consistent responses) for both groups. Performance on the weak dimension is much lower but considerably above the chance level of 50 per cent (around 65% consistent responses). The most important aspect of these data, as far as the hypotheses is concerned, is that performance on the weak dimension does not improve over days. Thus, there is no indication that S learns more and more about the cues on the weak dimension with overtraining.

Insert Figure 5 about here

Since performance does not improve on the weak dimension, one might formulate an alternative hypothesis which states that performance on the weak dimension, as compared with performance on the strong dimension, will be relatively poorer for the MA 3-5 Group than for the MA 6-8 Group. However, the data presented in Figure 5 do not support this alternative hypothesis. Performance on both strong and weak dimensions is highly similar for both MA groups. This statement is supported statistically by the nonsignificant interaction of dimension and MA in the analysis presented in Table 3.

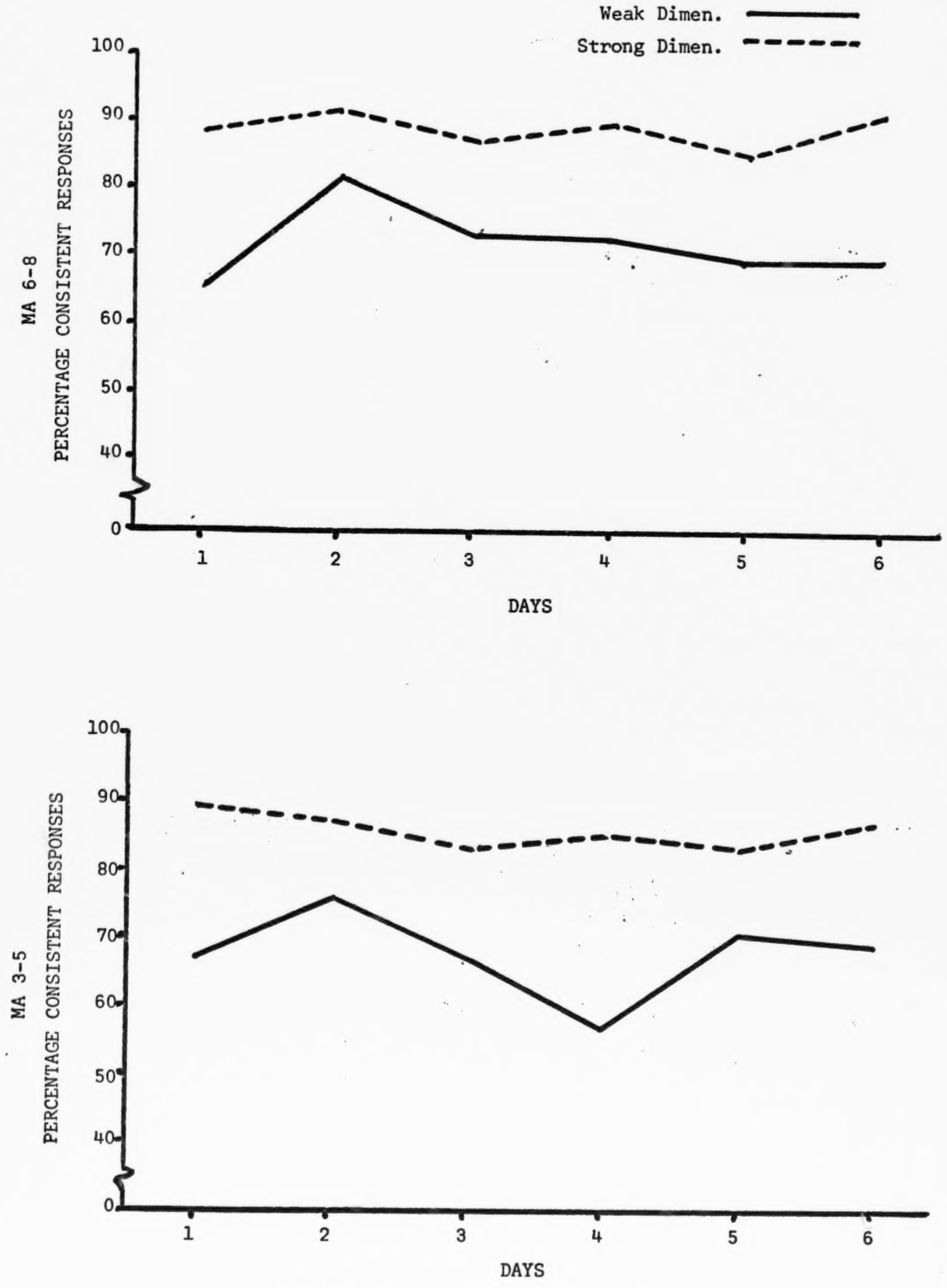

Figure 5. Performance on strong and weak dimensions for the two MA Groups separately.

Compounding. The analysis of variance yielded a significant main effect for compounds. Figure 6 shows the transfer performance of the two MA groups on tests in which the positive (C_1 and F_1) and negative (C_2 and F_2) compounds were retained. Overall, performance is superior on trials where the negative compound is retained. Thus, avoidance of the negative compound seems to be stronger than approach to the positive compound.

Insert Figure 6 about here

This finding is in direct conflict with the results of an experiment reported by House and Zeaman (1963). In their experiment, Ss with a mean MA of around 6 yrs. showed stronger approach to positive compounds. This conflict in results may be due to procedural differences between the two studies. While the present experiment involved the learning of a single problem and transfer tests, the House and Zeaman experiment employed a learning-set procedure in which each S learned many problems.

The interaction of compounds and MA approached statistical significance. The data shown in Figure 6 indicate that while both groups evidenced strong avoidance of the negative compound, approach to the positive compound was weaker in the MA 3-5 Group. House and Zeaman also reported a direct relationship between the strength of approach to the positive compound and MA.

One other effect in the two analyses, the interaction of dimension and compound, approach statistical significance. This interaction can be interpreted more meaningfully in terms of strong and weak dimensions than in terms of color and form dimensions. The dimension factors in the different analyses are mainly confounded anyway, since form was the strong dimension and color was the weak dimension for all but 3 Ss. Figure 7 is a histogram showing the percentage of responses consistent with problem solution for the four transfer tests (S_1, S_2, W_1 and W_2). Performance on the strong dimension is at a high level regardless of whether it is the positive or negative compound which is retained. However, performance on the weak dimension is considerably poorer when the positive compound is retained. Apparently, performance is at such a high level when the strong component cues are available that the differential contributions of positive and negative compounds are unimportant. When only the cues along the weak dimension are available, the differential strengths of avoidance of the negative compound and approach to the positive compound are evidenced.

Insert Figure 7 about here

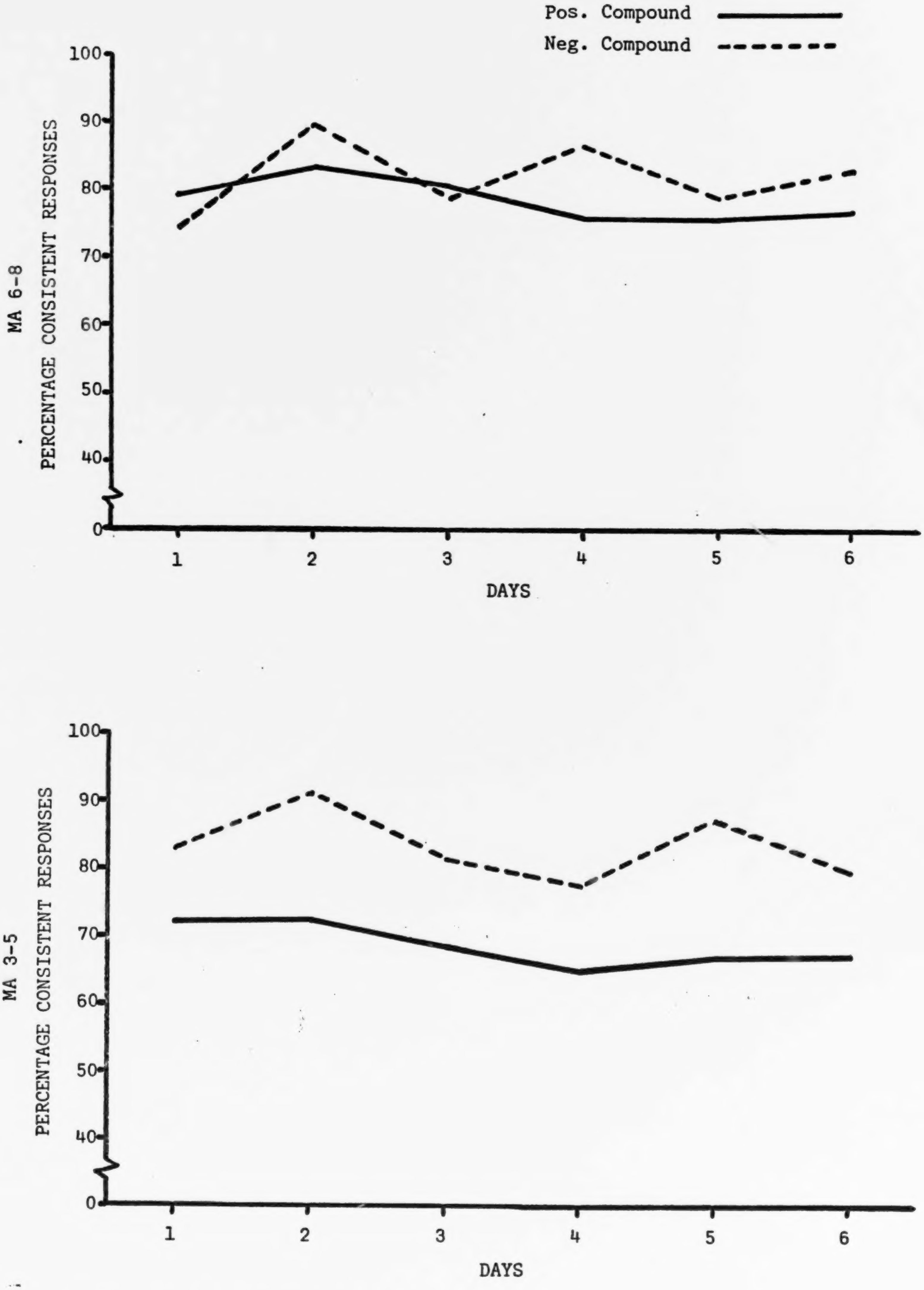

Figure 6. Performance on transfer tests involving the positive and negative training compounds for the two MA groups separately.

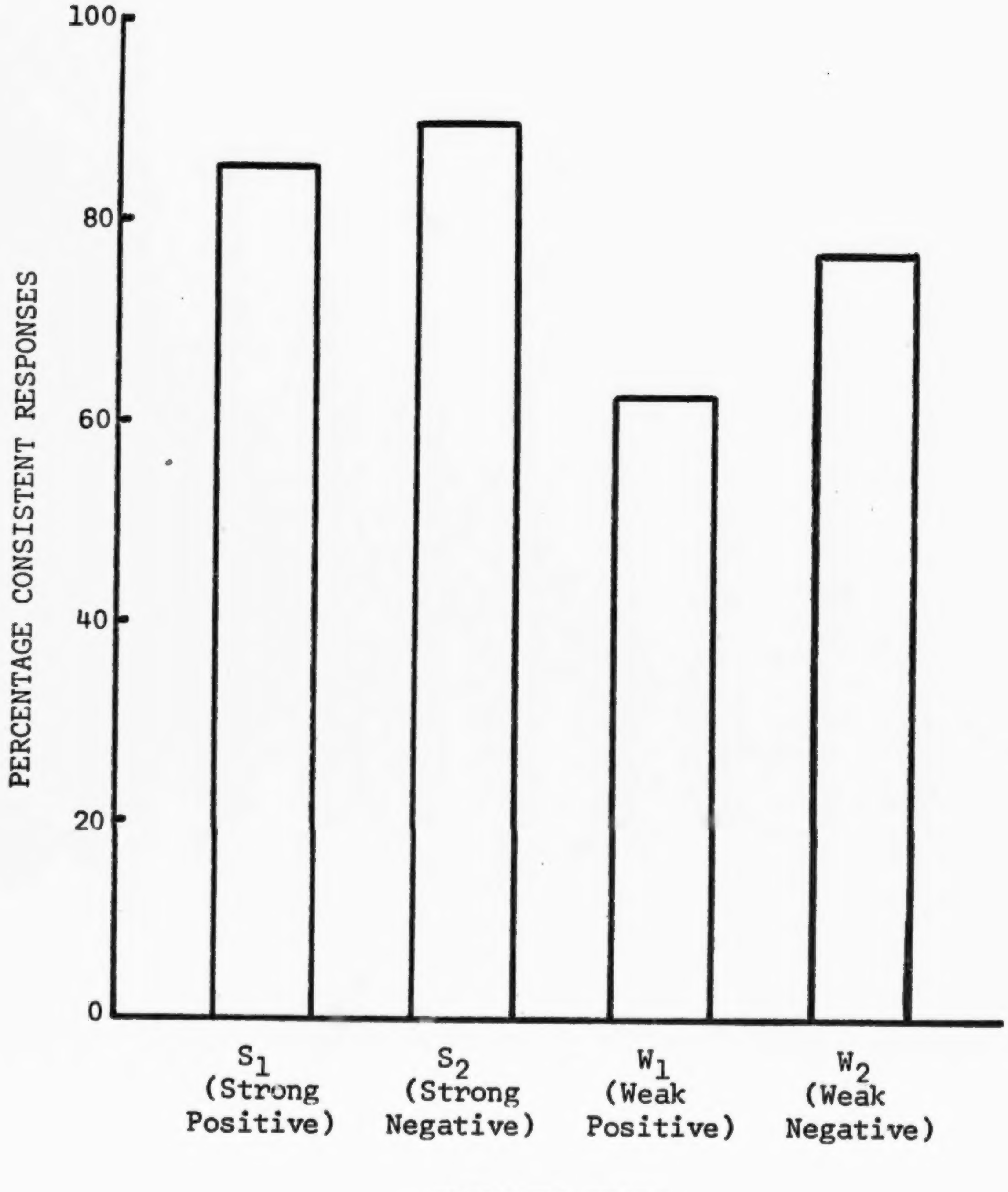

Figure 7. Performance of all Ss on the four transfer tests.

Conclusions

The results of this experiment are not consistent with the predictions from Sutherland's model since S did not learn more and more as overtraining progressed about the cues on the weak dimension. Paradoxically, performance on the weak cues exceeded the 50 per cent chance level throughout overtraining, indicating that S had learned something about the cues available on these tests. However, above chance performance on these tests may well have been due to attention to the compound color-form dimension.

The most general form of the Zeaman and House theory fares little better. This theory assumes that S attends to only one dimension at a time. The results show that S had learned about the cues on at least two dimensions. The data clearly indicate that S learned something about the cues on the compound dimension. In addition, the difference in transfer performance on the strong and weak dimensions must be ascribed to learning about the cues on the strong dimension. This follows since the available compound cues were the same for the transfer tests on the color and form dimensions.

Zeaman and House have proposed an alternative, more complex, model which seems slightly more adequate with respect to the present results. The assumption is made that S can attend to more than one dimension on a given trial. However, this model does not incorporate the notion of differing strengths of attending responses as does Sutherland's theory. The amount of learning is constant for the cues on the dimensions to which S attends. The finding that S learns about the cues on more than one dimension is consistent with this model. However, this model also predicts continued learning about the cues on the dimensions to which S is attending until some high asymptotic level is reached. Thus, if S is attending to the compound dimension, learning about the cues on this dimension should continue during overtraining. Such apparently was not the case in the present experiment.

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Discrimination Shift Performance of Kindergarten Children as a Function of Variation of the Irrelevant Shift Dimension

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Abstract

The learning of intradimensional (ID), reversal (RV), and extradimensional (ED) shifts by kindergarten children was studied under 2 conditions of variation of the irrelevant shift dimension. This dimension varied between trials and was constant within trials for half of the Ss and varied within trials for the remainder of the Ss. ID and RV shifts were learned faster than ED shifts only when the irrelevant shift dimension varied within trials. No learning differences were obtained among the 3 shifts when the irrelevant shift dimension was constant within trials. These results indicate that negative transfer of a mediating response to the previously relevant dimension does not pertain to the ED shift unless this dimension becomes irrelevant and varies within trials.

Discrimination Shift Performance of Kindergarten Children as a Function of Variation of the Irrelevant Shift Dimension

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A developmentally-oriented model of discrimination learning has been presented by Kendler and Kendler (1962). This theory posits that as development proceeds the nature of the learning process changes from a single-link, S-R action to a covert, mediational action. The former process regulates the discrimination learning of animals and young children (below the age of approximately 5 years), while the latter process regulates the learning of older humans.

Kendler and Kendler have cited as support for their formulation the results of experiments comparing performance on reversal (RV) and extradimensional (ED) shifts. The latter are nonreversal shifts in which the relevant cues of the original discrimination are changed to those of a new stimulus dimension. The relative rates at which these problems are learned are viewed as reflecting the nature of the underlying process. The mediational position assumes that discrimination learning involves a chain of two responses--S must learn to make both a mediating response to the relevant stimulus dimension and an instrumental approach response to a specific cue along that dimension. Furthermore, both mediating and instrumental responses are assumed to transfer from one discrimination problem to another. The single-link position assumes that an associative link is formed directly between the positive stimulus and the overt response through the processes of acquisition and extinction. Transfer from one problem to another occurs via generalization from the positive stimulus of the first problem. From the mediational viewpoint, the ED shift involves negative transfer of the mediating response while the RV shift involves positive transfer of the mediating response (and negative transfer of the instrumental response). From the single-link viewpoint, only RV shifts involve a consistent source of negative transfer. Thus, Ss behaving in a single-link fashion, animals and young children according to Kendler & Kendler, will learn ED shifts faster than RV shifts, while Ss behaving in a mediational fashion, older humans, will learn RV shifts faster than ED shifts.

The results of several experiments have tended to lend support to the developmental-change hypothesis of Kendler and Kendler. It has been found consistently that mature human Ss learn RV shifts faster than

ED shifts (e.g., Isaacs & Duncan, 1962; Kendler & D'Amato, 1955). It also has been shown that rats (Kelleher, 1956) and preschool children (Kendler, Kendler, & Wells, 1960) learn ED shifts faster than RV shifts. Still further support has been garnered from the finding that kindergarten children learn RV and ED shifts at comparable rates, indicating perhaps that these children have matured to the point at which the transition takes place from single-link to mediational functioning (Kendler & Kendler, 1959).

In spite of the results of the foregoing experiments, the developmental-change hypothesis, in the light of recent experimentation, now appears questionable. The more recent experiments have compared performance on ED shifts with performance on intradimensional (ID) shifts. The ID shift is a nonreversal shift in which the relevant cues of the original discrimination are changed to new cues along the same dimension. From the mediational position, the ID shift involves positive transfer of the mediating response and, therefore, should be learned faster than the ED shift (negative transfer). From the single-link position, neither of the two shifts involve a consistent source of transfer and, therefore, they should be learned at comparable rates. The developmental-change hypothesis would lead one to expect no ID-ED shift differences in animals or young children. However, ID shifts have been learned faster than ED shifts by rats (Shepp & Eimas, 1964), preschool children (Dickerson, 1966; Garber & Ross, in press; Mumbauer & Odom, 1967), mental retardates with MAs of around 4.5 years (House & Zeaman, 1962), and kindergarten children, who supposedly were at the point of transition (Eimas, 1966). Reversal shifts also were learned faster than ED shifts by the Ss in the studies of Dickerson, House and Zeaman, and Mumbauer and Odom. Finally, the results of one other study also showed that RV shifts were learned faster than ED shifts by preschool children (Marsh, 1964), but only when overtraining was given on the original problem. Clearly, the results of these experiments contradict the developmental-change hypothesis.

The foregoing discussion indicates that while the results of some experiments tend to support the notion of a change at around 5 years of age from single-link to mediational functioning, the results of other experiments are at odds with such a change. The disparate findings have lead several workers (e.g., Dickerson, 1966; Eimas, 1965; Wolff, 1967) to the conclusions (a) that there is no developmental change; the discrimination learning of animals and young children, as well as that of older humans, is regulated by a mediational mechanism; and (b) that the experimental results which tend to support the developmental-change hypothesis can be better explained on procedural grounds. The present experiment is concerned with a procedural factor, dimensional variation, which seems to be important in this respect. Several other procedural factors also seem pertinent here but these have been discussed elsewhere in detail (e.g., see Mackintosh, 1965; Shepp & Turrisi, 1966; Smiley & Weir, 1966; Wolff, 1967).

Kendler and Kendler (1959) found that RV and ED shifts were learned at comparable rates by kindergarten children. This result is somewhat surprising when viewed in light of the fact that even younger children have been shown to learn RV shifts faster than ED shifts (Dickerson, 1966; Mumbauer & Odom, 1967). However, the experiments differed procedurally. In the Kendler and Kendler study, S first was given a two-dimensional discrimination problem with one dimension relevant and the other irrelevant and varying within trials. Upon reaching criterion on the original problem, S underwent either an RV or an ED shift during which the irrelevant dimension varied between trials but was held constant within trials. The two other experiments were procedurally similar to the Kendlers' with the exception that during the shift phase the irrelevant dimension varied within trials. Eimas (1965) suggested that the ED shift becomes a much easier problem when the irrelevant dimension is constant within trials, while this factor has little effect upon the RV shift. He reasoned the mediating response to the relevant dimension of the original problem is not elicited in the ED shift unless there is within trial variation of the dimension. Since the interfering effects of this response are what slow the learning of the ED shift, a much easier problem results when the previously relevant dimension is made constant. Thus, Eimas is not surprised that Kendler and Kendler failed to obtain faster learning of the RV shift than of the ED shift. An experiment by Dickerson (1967) lends support to Eimas' suggestion; ED shifts were learned much faster by kindergarten children when the irrelevant dimension varied between trials (constant within trials) than when it varied within trials.

The present experiment compares the learning of ID, RV, and ED shifts by kindergarten children under two conditions of irrelevant dimension variation in the shift phase, (a) variation between trials and constant within trials and (b) variation within trials. Given the preceding analysis, it is expected that RV and ID shifts will be learned faster than ED shifts under the latter condition, while such differences will be diminished greatly, or absent, under the former condition. Tighe and Tighe (1967) have made a similar comparison of RV and ED shift performance in both 4-year-old and 10-year-old children. The results of their experiment will be discussed later. The present experiment differs from that of Tighe and Tighe in that the ID shift is included and that kindergarten children are the Ss, as in the Kendler and Kendler study.

Method

Subjects--The Ss were 96 children enrolled in kindergarten classes in the public schools of Manchester, Connecticut, and of Lynbrook, Long Island, New York. The Ss were assigned randomly to the 12 subgroups involved in the experiment (8 Ss/subgroup).

Apparatus--The apparatus was a portable version of the Wisconsin General Test Apparatus. Components of the apparatus were (a) a 26x20-in. panel which served as a screen between S and E and (b) a sliding tray containing two 2-in. reward cups centered 10 in. apart. The apparatus was mounted on a small table with a chair for E on one side and a chair for S on the other. A slotted metal container was placed on a short stool on the right side of S's chair. The purpose of this container was to hold the plastic chips which served as rewards.

There were 16 different stimulus objects consisting of all combinations of four colors: red, green, blue, and yellow; and four forms: circle, triangle, square, and T. The forms were cut from 1/4 in. Masonite and mounted vertically on 4x4-in. gray Masonite bases. Maximum height and width of each stimulus was 2 in.

General Procedure--To bait the reward cup, *E* pulled the sliding tray behind the screen, then pushed the tray directly in front of *S* to begin a trial. The *S*'s response was lifting the stimulus object and uncovering the reward cup. Red, white, and blue plastic chips, randomly alternated, served as rewards. A noncorrection procedure was used. In addition to the chip, correct responses were rewarded verbally with "good" and incorrect responses were punished with "no."

The experimental treatment for a given *S*, including both the original problem and the shift problem, was administered in a single session. Criterion of learning for both phases was seven correct responses in each of two consecutive blocks of eight trials. Although the procedure assured the learning of the original problem, training on the shift problem was terminated at the end of 72 trials if *S* had not yet attained criterion.

Original Problem--A random half of the *Ss* first received training on problems with color as the relevant dimension and form as a variable-irrelevant (within trials) dimension. For the other half of the *Ss*, form was the relevant dimension and color was the irrelevant dimension. From the four colors and four forms available, each *S* was randomly assigned a pair of relevant cues from one dimension and a pair of irrelevant cues from the other. Thus, a particular *S* might have red and green as relevant cues, circle and triangle as irrelevant cues. Since the form cues were irrelevant within trials, *S* would be presented with a red triangle vs. a green circle on some trials and a red circle vs. a green triangle on other trials. Each stimulus would appear in each of the two spatial positions (left and right), creating four different types of trials. Each type of trial appeared twice in each block of eight trials. In this manner, each irrelevant cue (e.g., circle and triangle, left and right) was associated with reward on half of the trials. The order of trials within trial blocks was random with the restriction that no two consecutive trials were identical.

Training Procedure--At the start of the session, each *S* was brought individually into the room in which the treatments were administered and was seated opposite *E* at the table containing the apparatus. The *E* told *S* that he was going to "play the chip game," and demonstrated how the chips were to be obtained. The *E* then told *S* that a chip would be hidden under one of the two objects presented on each trial and that *S* was to try to find the chip each time. [illegible]ining then was begun on the original problem. In order to facilitate the learning of the original problem, a special training procedure was instituted at the end of any trial block in which *S* made five or fewer correct responses. The tray was arranged with the two positive stimulus objects on the left side and the two negative objects on the right side. Without mentioning the color or form of the cues, *E* pointed to the two positive stimulus objects and said, "These things are right. The chip is always under these."

The E then pointed to the two incorrect stimulus objects saying, "These things are wrong. The chip is never under these." If S made six or more correct responses in a trial block, then E said nothing.

This special training procedure is similar to that used in several other studies after S failed to reach a learning criterion in a specified number of trials (e.g., Sanders, Ross, & Heal, 1965; House & Zeaman, 1962). The procedure was employed from the outset of the original problem in this experiment since previous work (Dickerson, 1967) indicated that a large proportion of kindergarten Ss eventually require it anyway. The use of special training was deemed preferable to the alternative of dropping Ss who failed to learn the original problem from the experiment and then replacing them with other Ss from the available pool. The rationale for this preference has been presented elsewhere (Dickerson, 1967; House & Zeaman, 1962).

Shift Problem--The color-relevant and form-relevant training groups each were divided evenly among the three types of shifts (ID, RV, and ED). Each of these groups were divided again into subgroups for which the irrelevant dimension of the shift problem either (a) varied within trials or (b) varied between trials and was constant within trials. A sample problem in which the irrelevant dimension varied within trials was presented in a previous section. Between trial variation of the irrelevant dimension can be demonstrated by considering again the S with red and green as relevant cues, circle and triangle as irrelevant cues. On some trials S would be presented with a red circle vs. a green circle and on other trials with a red triangle vs. a green triangle.

The Ss receiving ID and ED shifts were assigned two new cues along both the color and form dimensions. The dimension which was relevant in the original problem remained relevant in the ID shift, while the irrelevant dimension of the original problem became relevant in the ED shift. The Ss receiving RV shifts were assigned two new cues only along the irrelevant dimension.

The general procedure for the shift problem was the same as for the original problem except that special training was omitted. Instead, at the end of any trial block in which S made five or fewer correct responses E said, "Remember, pay attention to the two things and see if you can learn to find the chip every time." Transition from the original problem to the shift problem was made without any comment from E.

Results

Original Problem--The performances of the various subgroups on the original problem are summarized in Table 1 in terms of mean errors

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Insert Table 1 about here

Table 1

Mean Errors Through Criterion

on the Original Problem

Shift		N	Between Trial	Within Trial
ID	Form-Form	8/Subgroup	6.38	5.50
	Color-Color	8/Subgroup	6.50	7.00
	Total	16/Group	6.44	6.25
RV	Form-Form	8/Subgroup	3.38	4.88
	Color-Color	8/Subgroup	6.62	6.12
	Total	16/Group	5.00	5.50
ED	Color-Form	8/Subgroup	6.00	6.00
	Form-Color	8/Subgroup	3.88	4.38
	Total	16/Group	4.44	5.19

through criterion. All subgroups learned the original problem quickly, although learning seems to have been slightly faster when form was the relevant dimension. In an analysis of variance (ShiftxVariationxRelevant Dimension) of the errors-through-criterion scores, the Relevant-Dimension effect attained significance, $F(1,84)=4.92$, $p<.05$, giving support to the preceding statement. No other effect even approached statistical significance. The rapid learning of the original problem probably was due to the use of the special training procedure.

Shift Problem--Shift performance is summarized in Table 2, also in terms of mean errors through criterion. The number of errors in 72 trials was the errors-through-criterion score assigned to those *Ss* not attaining criterion. Inspection of Table 2 shows that the ED shift was learned much more slowly than the ID and RV shifts when the irrelevant dimension varied within trials. On the other hand, the three shifts were learned at comparable rates when the irrelevant dimension varied between trials and was constant within trials.

Insert Table 2 about here

Two separate two-way analyses of variance (ShiftxRelevant Dimension) were performed on the errors-through-criterion scores, one for each type of irrelevant dimension variation. Under between-trial variation, the Shift effect was nonsignificant, $F<1$. Under within-trial variation of the irrelevant dimension, the Shift effect was significant, $F(2, 42)=14.84$, $p<.001$. The analyses also showed that the shift problems were learned faster when form was the relevant dimension; $F(1, 42)=6.22$, $p<.01$, in the between-trial analysis and, $F(1, 42)=38.50$, $p<.001$, in the within trial analysis. The ShiftxRelevant Dimension interaction was nonsignificant for the between trial analysis, $F<1$, and significant for the within trial analysis, $F(2, 42)=7.56$, $p<.01$. Inspection of Table 2 indicates that the significant interaction was due to larger shift differences when color was the relevant dimension than when form was the relevant dimension.

Discussion

The results of this experiment showed that ID and RV shifts were learned faster than ED shifts by kindergarten children when the irrelevant shift dimension varied within trials. No learning differences were obtained among the three shifts when the irrelevant shift dimension was constant within trials. Table 2 shows that the ED shift was a much harder problem under the within-trial situation than it was under the constant situation. On the other hand, the learning of ID and RV shifts was affected little, if at all, by the difference in irrelevant dimension variation. Thus, the experimental results are consonant with Eimas' (1965) suggestion that negative mediating-response transfer is not involved in the ED shift unless the relevant dimension of the original problem is irrelevant and varies within trials. Apparently,

Table 2

Mean Errors Through Criterion on the Shift Problem

Shift		N	Between Trial	Within Trial
ID	Form-Form	8/Subgroup	0.50	1.00
	Color-Color	8/Subgroup	7.50	11.50
	Total	16/Group	4.00	6.25
RV	Form-Form	8/Subgroup	2.10	3.50
	Color-Color	8/Subgroup	11.60	9.80
	Total	16/Group	6.85	6.65
ED	Color-Form	8/Subgroup	4.10	6.40
	Form-Color	8/Subgroup	9.50	34.10
	Total	16/Group	6.80	20.25

mediating responses are made primarily to dimensions which vary within trials, at least when prior training has been given on simultaneous discrimination problems.

The results also allow a consistent interpretation of the seemingly disparate findings of Kendler and Kendler (1959) on the one hand and Dickerson (1966) and Mumbauer and Odom (1967) on the other. Kendler and Kendler employed a procedure in which the irrelevant shift dimension was constant within trials. Thus, it is not surprising that they found kindergarten children to learn RV and ED shifts at comparable rates. In the other two studies, preschool children learned RV shifts faster than ED shifts with the irrelevant shift dimension varying within trials. One thus is lead to the conclusion that kindergarten children are not at a point of transition from single-link to mediational functioning, but rather that they definitely learn in a manner consistent with the mediational position. Indeed, rats learn ID shifts faster than ED shifts indicating that even they are mediating Ss (Shepp & Eimas, 1964).

Several studies have yielded results showing that infrahuman Ss learn ED shifts faster than RV shifts. In most of these studies, the irrelevant shift dimension was constant within trials. In two of the experiments, however, the irrelevant shift dimension varied within trials. Kelleher (1956) found that rats learned ED shifts faster than RV shifts, and Brookshire, Warren, and Ball (1961) reported similar findings for both rats and chickens. How can these results be reconciled with those of Shepp and Eimas? As other have noted (Mackintosh, 1965; Wolff, 1967; Zeaman & House, 1963), the RV shift involves negative transfer of the instrumental response, as well as positive transfer of the mediating response and, therefore, may not always provide a positive transfer situation. In fact, the mediational position predicts faster learning of RV shifts than of ED shifts only when the instrumental response extinguishes faster than the mediating response. If the opposite is true, then faster learning of ED shifts is predicted. Since human Ss generally learn RV shifts faster, they must extinguish the instrumental response more quickly than the mediating response. However, infrahuman Ss may extinguish the mediating response more quickly than the instrumental response. Evidence already is available which suggests that this is true of rats (Goodwin & Lawrence, 1955).

The results of one other experiment also are pertinent to the present findings. Tighe and Tighe (1967) studied the RV and ED shift learning of 4-year-old and 10-year-old children with the irrelevant shift dimension varying within trials for half of the Ss and constant within trials for half of the Ss. The pattern of results for the 10-year-olds were the same as those obtained with kindergarteners in the present study. However, the 4-year-olds learned ED shifts faster than RV shifts regardless of whether the irrelevant shift dimension varied within trials or was constant within trials. While these results are not necessarily in conflict with those of the present experiment, they are in conflict with the results reported by Dickerson (1966) and Mumbauer and Odom (1967). Thus, whether or not there is a developmental change in the relative rates at which RV and ED shifts are learned cannot be ascertained at present. If there is a developmental change, it seems likely, given the available evidence, that it is not one of a transition from single-link to mediational functioning. More likely, is a developmental change in the relative rates at which instrumental and mediating responses are acquired and extinguished.

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Training Conditions and Dimensional Transfer in the Discrimination Learning of Retardates

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Abstract

The intradimensional (ID) and extradimensional (ED) shift performance of retarded Ss was studied under two conditions: (a) where the irrelevant dimension of the original problem varied within trials, and (b) where it varied between trials and was constant within trials. The results showed that ID shifts were learned faster than ED shifts regardless of the manner of variation of the irrelevant dimension in the original problem. The finding of an ID-ED shift difference under the between trial condition contrasts with the prior finding of no ID-ED shift difference when the irrelevant training dimension is constant both within and between trials.

Training Conditions and Dimensional Transfer in the Discrimination Learning of Retardates

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Chaining theories (Lovejoy, 1966; Sutherland, 1964: Zeaman & House, 1963) assume that discrimination learning involves a chain of two responses--S must learn both to attend to the relevant stimulus dimension and to approach a specific cue along that dimension. Furthermore, both attentional and instrumental responses are assumed to transfer from one discrimination problem to another. The chaining formulation yields the novel prediction that the second of two discrimination problems will be learned more quickly when the same dimension is relevant in both problems than when different relevant dimensions are presented. Theoretically, the former sequence of problems, the intradimensional (ID) shift, involves positive transfer of the attentional response, while the latter sequence, the extradimensional (ED) shift, involves negative transfer of the attentional response.

Comparisons of ID and ED shifts generally have supported the notion that attentional responses are learned and transferred (Dickerson, 1966; House & Zeaman, 1962; Shepp & Eimas, 1964). However, ID shifts are not always learned faster than ED shifts. When certain procedures are used, the two shifts are learned at comparable rates. The present experiment is directed at a more thorough understanding of one of the situations in which ID-ED shift differences are not found.

Studies yielding ID-ED shift differences typically have employed a procedure whereby S first is given a two-dimensional discrimination problem with one dimension relevant and the other irrelevant and varying within trials. Upon reaching criterion on the original problem, S undergoes either an ID or an ED shift involving the same variable dimensions as the original problem. Both House and Zeaman (1962), using retardates, and Turrisi, Shepp, & Eimas, using rats, report that ID-ED shift differences are not obtained when a seemingly minor change is made in the original problem. If the irrelevant dimension of this problem is constant, i.e., does not vary, then the shift differences disappear.

House and Zeaman (1963) have suggested a possible interpretation of the failure to obtain an ID-ED shift difference in the situation where the irrelevant training dimension is constant. They suggest that the constant-irrelevant dimension combines with the relevant dimension to form a compound dimension. This compound dimension also is relevant in the original problem, and the Ss may be learning to attend to it. When the Ss are shifted and a variable-irrelevant dimension is introduced, the compound dimension is irrelevant (or equally relevant) for both ID and ED shifts. Thus, the two shifts are learned at comparable rates.

The present experiment is a test of the foregoing notion. Here, ID and ED shift learning in retardates is studied with the original training dimension varying between trials and constant within trials. In this situation, the compound dimension is not relevant and the original problem must be learned by attending to the relevant component dimension. If the Zeaman and House position is correct, then ID-ED shift differences should appear.

Method

Subjects--The Ss were 48 mentally defective individuals, 29 males and 19 females, selected from the pool of Ss at the Mansfield State Training School. Their MAs ranged from 52 to 86 months, with a median of 70 months: their IQs from 25 to 48 with a median of 36.5. The Ss were assigned randomly to the eight subgroups in the experiment.

Apparatus--A modified version of the Wisconsin General Test Apparatus was used. The S and E sat facing each other with a one-way screen interposed. A 30 x 12-inch stimulus tray containing two circular food wells 3 inches in diameter and separated by 12 inches from center to center could be directly presented in front of S by pushing it under a space beneath the one-way screen. The apparatus was painted gray.

There were 36 different stimulus objects consisting of all combinations of six colors: red, green, yellow, blue, pink, and brown; and six forms: circle, triangle, square, plus, diamond, and T. The forms were cut from 1/4-inch Masonite and mounted vertically on 4 x 4-inch gray Masonite bases. Maximum height and width of each stimulus was 2 inches.

General Procedure--To bait the food cup, E pulled the sliding tray behind the screen, then pushed the tray directly in front of S to begin a trial. The S's response was lifting the stimulus and uncovering the food cup. Rewards were M & M candies. The E said "Good" if the first response was correct, and "No" if it was not. Immediate correction of wrong responses was allowed. Position of the correct stimulus, left or right, was varied according to a Gellermann series.

Thirty trials were given per day on all three problems: pretraining, original, and shift. Criterion of learning was 24/30 correct during a single daily session. For the original problem, 90 overtraining trials were given beyond criterion. Failure criterion was 150 trials without reaching criterion.

Pretraining--Before entering any of the experimental conditions, S learned to criterion a "junk" discrimination problem. Each S was randomly assigned a pair of "junk" stimuli, i.e., stimuli differing multidimensionally in size, shape, color, texture, etc., from the available collection.

Original Problem--The 48 Ss then were split into two groups of 24 Ss. For one of these groups, color was the relevant dimension and form was the irrelevant dimension. For the other group, form was the relevant dimension and color was the irrelevant dimension. These groups were divided again in a manner such that (a) the irrelevant dimension was variable within trials for half of the Ss in each and (b) the irrelevant dimension was variable between trials for the other half of the Ss. From the six color and six forms available, each S was assigned randomly a pair of relevant cues from one dimension and a pair of irrelevant cues from the other dimension. Thus, a particular S might have red and green as relevant cues, triangle and circle as irrelevant cues. If this S were one for whom the irrelevant dimension varied within trials, he would be presented with red triangle vs. green circle on some trials and red circle vs. green triangle on other trials. If, on the other hand, this S were one for whom the irrelevant dimension varied between trials, he would be presented with a red triangle vs. green triangle on some trials and red circle vs. green circle on other trials.

Special Training--In order to facilitate the learning of the original problem, a special training procedure was administered at the beginning of each daily session prior to criterion performance. The tray was arranged with the two positive stimulus objects on the left and the two negative objects on the right side. Without mentioning the color or form of the cues, E pointed to the two positive stimulus objects and said, "These blocks are right. The candy is always under these blocks." The E then pointed to the two incorrect stimulus objects saying, "These blocks are wrong. The candy is never under these blocks."

This special training procedure is similar to that used in several other studies after S failed to reach a learning criterion in a specified number of trials (Dickerson, 1967; House & Zeaman, 1962). The procedure was employed from the outset of the original problem since previous work (House & Zeaman, 1962) indicated that a large proportion of retarded Ss eventually require it anyway. The use of special training was deemed preferable to the alternative of dropping Ss who failed to learn the original problem from the experiment and then replacing them with other Ss from the available pool. The rationale for this preference has been presented elsewhere (Dickerson, 1967).

Shift Problem--The general procedure for the shift problem was the same as for the original problem except that special training was omitted. The four training groups: form relevant-within trial irrelevant, form relevant-between trial irrelevant, color relevant-within trial irrelevant, color relevant-between trial irrelevant: were evenly divided between the two shift conditions, ID and ED. Each S was assigned randomly two new cues along both the color and form dimensions. The dimension which was relevant in the original problem remained relevant in the ID shift, while the irrelevant dimension of the original problem became relevant in the ED shift. The irrelevant shift dimension varied within trials for all Ss.

Results

Original Problem--The original problem was learned very quickly. The number of errors through criterion was counted for each S. The medians for the eight subgroups of the experiment ranged from 0 to 3 errors through criterion. The rapid learning of the original problem probably was due to the use of the special training procedure.

Shift Problem--Shift performance is summarized in Table 1 in terms of median errors through criterion. The number of errors in 150 trials was the errors-through-criterion score assigned to those Ss not attaining criterion. Medians are presented since, due to a few extreme scores, they seem to be more representative of central tendency than means. Learning curves plotting percentage correct responses against blocks of ten trials are presented for the four major groups in Figure 1. Inspection of Table 1 and Figure 1 indicate that the ID shift was learned faster than the ED shift both when the irrelevant dimension of the original varied within trials and when it varied between trials. The effects appear very strong when color was the relevant shift dimension and negligible when form was the relevant shift dimension.

Insert Table 1 and Figure 1 about here

The errors-through-criterion data were submitted to a 2 x 2 x 2 (Shift x Variation x Relevant Shift Dimension) analysis of variance, a logarithmic transformation of the raw data being used to correct for heterogeneity of variance. This analysis showed a significant Shift effect, $F(1,40) = 8.94$, $p < .01$, but a nonsignificant Shift x Variation interaction, $F < 1$. Thus, it appears that the ID shift was learned significantly faster than the ED shift regardless of the variation condition. The analysis also showed that the shift problem was learned faster when form was relevant than when color was relevant, $F(1,40) = 12.38$, $p < .01$. Finally, the Shift x Dimension interaction also attained statistically significance, $F(1,40) = 4.76$, $p < .05$. This result reflects the fact that ID-ED differences were much larger when color was relevant than when form was relevant.

Discussion

The results of this experiment indicate that the ID shift is learned faster than the ED shift when the irrelevant training dimension is variable between trials and constant within trials. This finding contrasts with the lack of an ID-ED shift difference when the irrelevant training dimension is constant both within and between trials (House & Zeaman, 1962; Turrisi, Shepp, & Eimas, 1967). The notion is supported that S solves the original problem in the latter situation by attending to a compound dimension which is irrelevant in the subsequent ID or ED shift.

Two other interpretations have been advanced to account for the absence of an ID-ED shift difference in the situation where the irrelevant training dimension is constant. Although neither is disproved completely by the present results, both become less appealing as a consequence of them. The first interpretation (House & Zeaman, 1962) has

Table 1

Median Errors Through Criterion

on the Shift Problem

Shift		N	Between Trial	Within Trial
ID	Form-Form	6/Subgroup	1.00	2.50
	Color-Color	6/Subgroup	2.00	4.00
	Total	12/Group	1.50	3.00
ED	Color-Form	6/Subgroup	2.50	4.00
	Form-Color	6/Subgroup	58.50	66.00
	Total	12/Group	22.00	21.50

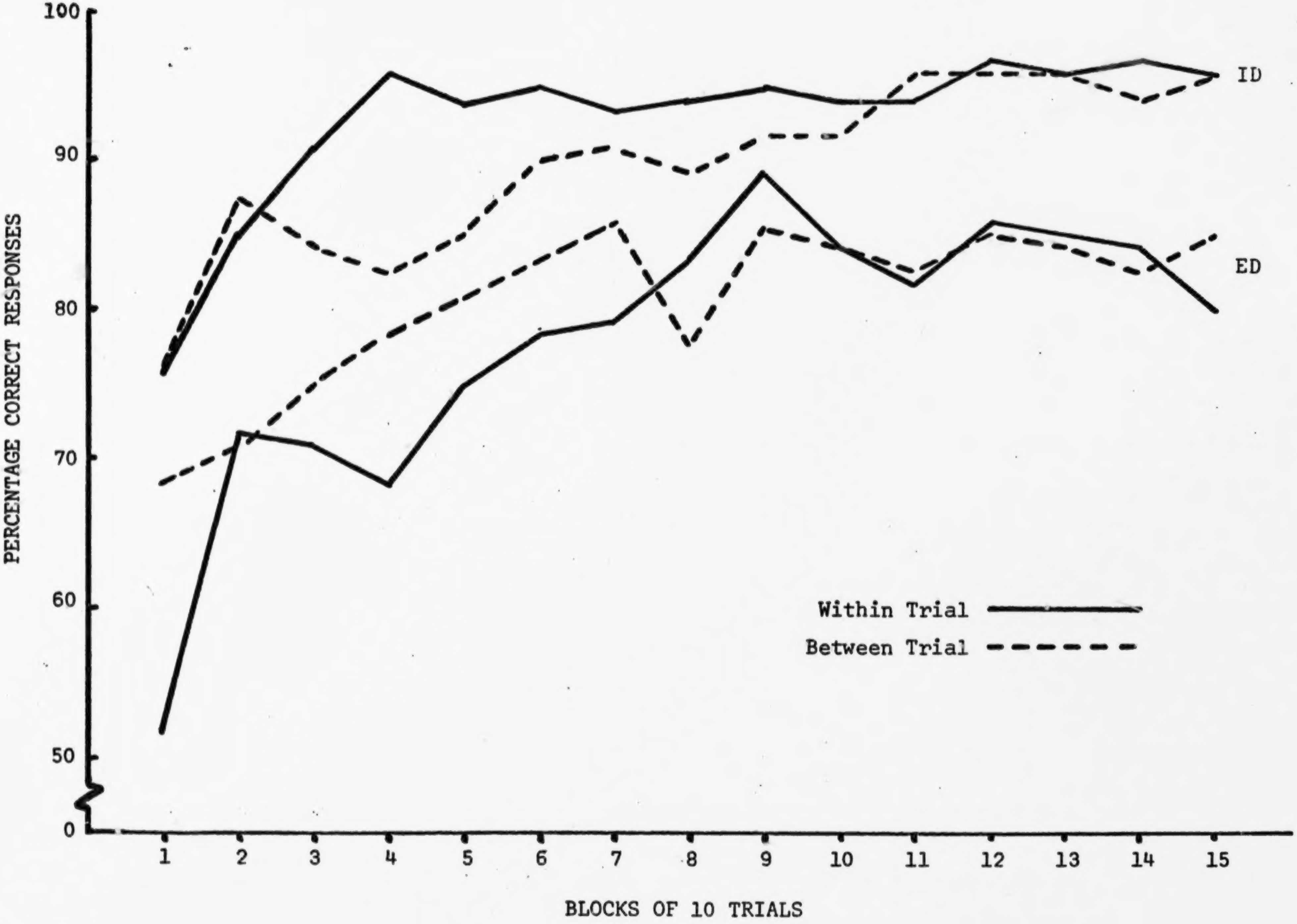

Figure 1. Forward learning curves for the four major groups.

to do with the effects of suddenly varying a previously constant dimension. Data are available (Dickerson, 1967) which suggest that when this is done there occurs an increase in the strength of the attentional response to the "novel" dimension. In the ID shift, the "novel" dimension would be irrelevant, thus interfering with learning. In the ED shift, the "novel" dimension would be relevant, thus facilitating learning. The net effect could be no ID-ED shift difference. If the present results are viewed in this way, then one is led to the following conclusion: Suddenly varying within trials a dimension which previously was constant within trials increases the strength of the attentional response to this dimension, but only when the dimension also was constant between trials.

The second interpretation assumes (a) that attentional responses are made only to variable stimulus dimensions and (b) that ID-ED shift differences depend upon the differential acquisition and extinction of attentional responses (Shepp & Turrisi, 1966). Given the former assumption, no differential learning and extinction of attentional responses would occur in the constant-irrelevant problem. Thus, ID and ED shifts would become equivalent problems. The present results suggest that if this account is correct, then it is necessary to give a dimension which varies between trials the same status as a dimension which varies within trials. Both alternative interpretations suffer from results indicating that attention is not readily elicited by dimensions which vary between trials and are constant within trials (Dickerson, Wagner, & Campione, 1968; Spiker & Lubker, 1964).

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Development of Hypothesis Testing in the Discrimination Learning of Human Subjects

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Abstract

An experiment is described which deals with the development of hypothesis behavior in discrimination learning. Groups of fifth-grade children, eighth-grade children, high school sophomores, and first-year college students were studied. Each S was trained on a series of 16 16-trial discrimination problems in which feedback was provided on some trials, outcome trials, and no feedback was provided on other trials, nonoutcome trials. The hypotheses used by S were inferred from the pattern of responses on nonoutcome trials. The data are only partially collected at present, and no analyses have been made. The data will be analyzed in order to assess the effects of different outcomes ("correct" and "wrong") on hypothesis behavior and to determine the efficiency with which the information provided by the feedback is utilized.

Development of Hypothesis Testing in the Discrimination Learning of Human Subjects

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The research with which this paper is concerned is focused upon developmental differences in problem-solving behavior. More specifically, the experiment deals with the use of "hypotheses" ("strategies," "predictions," "expectancies," and "sets" are alternative terms which have been employed) in the solution of two-choice, visual discrimination problems by human Ss at different stages of development. The experiment still is in progress: only about half of the data have been collected, and the scoring and analyzing of all the data remains. Thus, this paper will present the background and methodology of the experiment.

General Methodology--The two-choice discrimination learning paradigm provides a relatively uncomplicated situation for the study of problem-solving behavior. For the most simple problem of this type, that used with monkeys and very young children, two stimulus objects differing along one or more stimulus dimensions (color, size, and shape provide examples of stimulus dimensions) are presented simultaneously to S on each trial. A correct response occurs when S touches or lifts the object designated as correct by E prior to the experimental session. Usually a food or token reward is placed under the correct, or positive, stimulus prior to exposing the stimuli to S on each trial. Reward is withheld when S makes a response to the incorrect, or negative, stimulus. Learning is evidenced as an increase in responding over trials to the stimulus previously designated as positive.

The preceding situation requires modification for use with older human Ss. The procedure followed in the present experiment was introduced by Levine (1963). In Levine's procedure, the two stimuli differ multidimensionally (see Figure 1 for stimuli which vary on four dimensions). Learning involves responding consistently to a single value of only one of the variable dimensions. In addition, Levine introduces two distinct trial procedures. In the typical discrimination learning experiments with monkeys and young children, E uses a single procedure; one of the two responses always is rewarded while the other response never is rewarded. The analogous procedure with older humans is that one of the responses is followed by the word "right," the other by the word "wrong." With humans, E may have a second trial procedure: on some trials E may say nothing. These two types of trials will be called "outcome" and "nonoutcome" trials, respectively.

Theoretical Background--Several sources (e.g., Bower & Trabasso, 1964; Levine, Leitenberg, & Richter, 1964) present data which suggest that the choice responses made by adult humans during discrimination learning are organized by hypotheses (Hs) about problem solution. Furthermore, Levine (1963, 1966, 1967) has demonstrated that the particular H held by S may be inferred if outcomes are withheld for a few trials. The mechanics of such inference are described below. The necessary assumptions (Levine, 1966) are:

1. At the outset of a trial, S selects an H from some set of Hs. This H is a "state" and may be thought of as a prediction by S. Thus, S may predict that the blue stimulus is correct, regardless of its size, shape, etc., or that the stimulus on the left is correct, etc.

2. The set of Hs from which S samples is finite and is known exhaustively by E. In practice, Levine assumes specifically that each H is a prediction that one level of one of the variable dimensions is consistently correct. For the stimuli shown at the center of Figure 1 there are, then, only the eight Hs indicated by the columns.

Insert Figure 1 about here

3. If no outcome is given following S's choice, he keeps the same H for the next trial. Therefore, only one H will be utilized during successive nonoutcome trials.

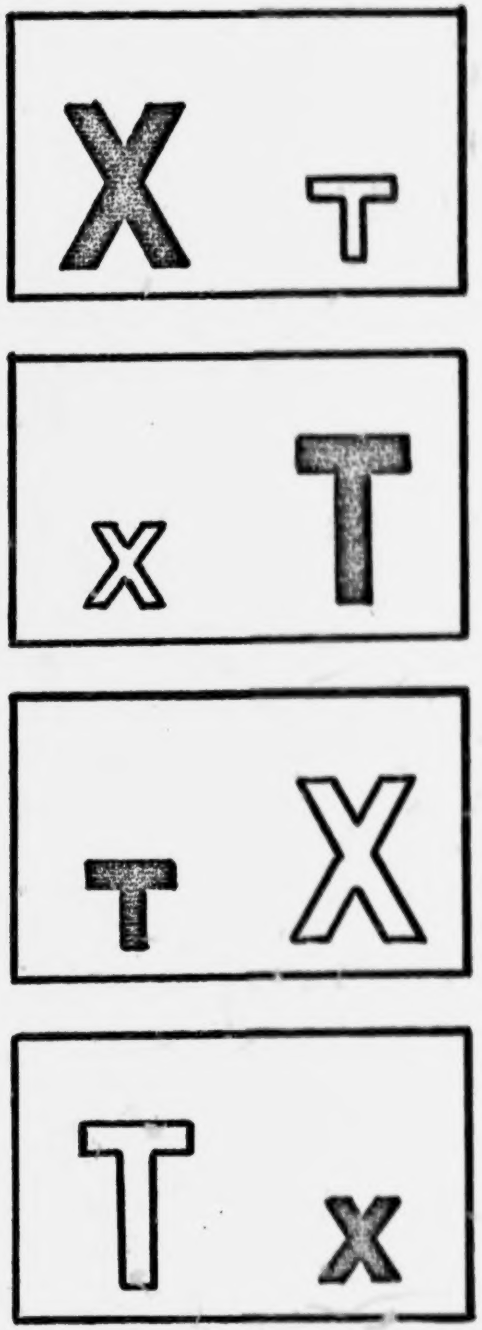
4. The S selects a stimulus in a manner such that, if his H were correct, he would always be right. For example, if S predicts that one of the shapes is correct, he will choose that shape, regardless of its size, color, or position, on every consecutive nonoutcome trial.

Assumptions 3 and 4 imply that over successive nonoutcome trials S will respond consistently to the aspect of the stimulus corresponding to the H adopted following the last outcome trial. The stimuli presented from trial to trial may be constructed in a manner such that a unique response pattern is yielded by each H. The four stimulus pairs illustrated in Figure 1 are so constructed. Suppose that these stimulus pairs are presented on four successive nonoutcome trials. The unique response pattern yielded by each of the eight possible Hs is shown in the columns of Figure 1. For example, if S predicts that black is the basis for solution, his responses will show the position pattern indicated in the column marked "black."

The response patterns of Figure 1 show either two or four responses to each position. According to the assumptions, no 3-1 patterns should occur. Levine allows for the occurrence of the eight possible 3-1 combinations with the following assumption:

5. On a given trial, there is certain constant probability that S will choose incorrectly. For example, an S who predicts that black is the basis for solution may "accidentally" choose the white stimulus on some trial. One such incorrect choice in a set of four nonoutcome

BLACK	X	LEFT	LARGE
LEFT	LEFT	LEFT	LEFT
RIGHT	LEFT	LEFT	RIGHT
LEFT	RIGHT	LEFT	RIGHT
RIGHT	RIGHT	LEFT	LEFT



SMALL	RIGHT	T	WHITE
RIGHT	RIGHT	RIGHT	RIGHT
LEFT	RIGHT	RIGHT	LEFT
LEFT	RIGHT	LEFT	RIGHT
RIGHT	RIGHT	LEFT	LEFT

Figure 1. Eight patterns of choices corresponding to each of the eight *Hs* when the four stimulus pairs are presented consecutively without outcomes.

trials will produce a 3-1 pattern. Levine (1966) has found that in practice, at least when college students are used as Ss, this probability of choosing incorrectly is very small (around .02). He suggests, therefore, that this assumption may be ignored with little distortion to the experimental results. However, the assumption is required to complete the treatment of the data.

The present experiment employed the foregoing assumptions and Levine's (1966) procedures in the study of the use of Hs by groups of Ss at different developmental stages. Compared were groups of fifth-grade children, eighth-grade children, high school sophomores, and first-year college students. Specific attention is directed to (a) the effects of succeeding outcome trials and (b) the differential effects of "correct" and "wrong" upon S's predictions.

Method

Subjects--The Ss were 40 fifth-grade children, 40 eighth-grade children, 40 high school sophomores, all obtained through public schools, and 40 first-year college students, obtained through the introductory psychology course at the University of Connecticut.

Materials and Procedure--The experiment involved the administration of a series of four-dimensional discrimination problems with stimuli of the sort illustrated in Figure 1. The stimuli were drawn in color, 2 1/2 inches apart, on 3 x 5-inch cards. The large letter was 1 inch in height and the small letter was 1/2 inch in height. A problem was composed of a set of stimulus cards all containing the same two letters and two colors. Different problems involved different pairs of letters and colors.

In order to meet Assumption 2, that S chooses only from among the eight simple Hs described in Figure 1, a preliminary instruction and training phase preceded the series of experimental problems. The S was seated across from E, was shown a sample stimulus card, and then received the following instructions:

> In this experiment you will be presented with several easy problems. Each problem consists of a series of cards like this one. Each card will always contain two letters, and the letters will be of two colors. You will also notice that the letters are of two different sizes and, of course, that one letter is on the left and one is on the right. Every card will be like this one except that the letters and colors will be different. One of the two stimuli is "correct" in the sense that I've marked it here on my sheet. For each card I want you to point to the stimulus which you think is correct and I will tell you whether you are right or wrong. Then you go on to the next card, again you make a choice, and again you can learn the basis for -my saying "correct" or "wrong." For any given problem, which of the two is correct will be determined by one and only one of the four characteristics. You can figure out whether it's because of the color,

> the letter, the size, or the position. The object for you is to figure this out as fast as possible so that you can choose correctly as often as possible.

The S then received training on six different pretraining problems. On the first four of these problems, an outcome was given following each trial. For example, consider the first of these problems in which the color (blue) was the basis for solution. The S received the deck of 24 cards face up. He responded to the stimulus of his choice by pointing, the appropriate outcome was given, and he then turned the card face down, out of the way. This procedure was followed for the first eight trials. After the eighth trial, E asked S for the solution. If S gave the correct solution, training on Problem 1 was stopped and training on Problem 2 was begun. If S was unable to give the correct solution, E said, "Okay, why don't you try a few more. Remember, one of the colors, one of the sizes, one of the letters, or one of the positions is always correct." The S then received another eight trials and, at the end of Trial 16, was asked for the solution. If S gave the correct solution, then he went on to Problem 2. If he did not produce the correct solution, E said, "On this problem, the blue letter is always correct. Let's see if you can get all the rest right." The S then received an additional eight trials on Problem 1 and, following this training, moved on to Problem 2. The same procedure was followed on each of the next three pretraining problems, i.e., for Problems 2, 3, and 4. The solutions to these problems were the left side, the letter O, and the large size, respectively. If S was unable to give the correct solution to Problem 4 by the end of Trial 16, then the experimental procedure was terminated for S, and he was replaced with a new S from the available pool.

The S then was instructed for the next two pretraining problems with this statement:

> In the last problems I said "correct" or "wrong" after each card. For the rest of the problems I will not always tell you whether you are right or not. After some cards, I will say nothing. Don't let that disturb you. Try to be right all the time. Remember, one of the letters, colors, sizes, or positions is always correct for a given problem.

Problems 5 and 6 then were presented. These problems had sets of nonoutcome trials interspersed among the outcome trials. (see Figure 2). For all Ss the color yellow and right side were correct, respectively.

Experimental Problems--Each S next received 16 16-trial problems in which an outcome always was given on the first, sixth, eleventh, and sixteenth trials. The stimuli for each problem were arranged with special restrictions. In a four-dimensional simultaneous discrimination

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Insert Figure 2 about here

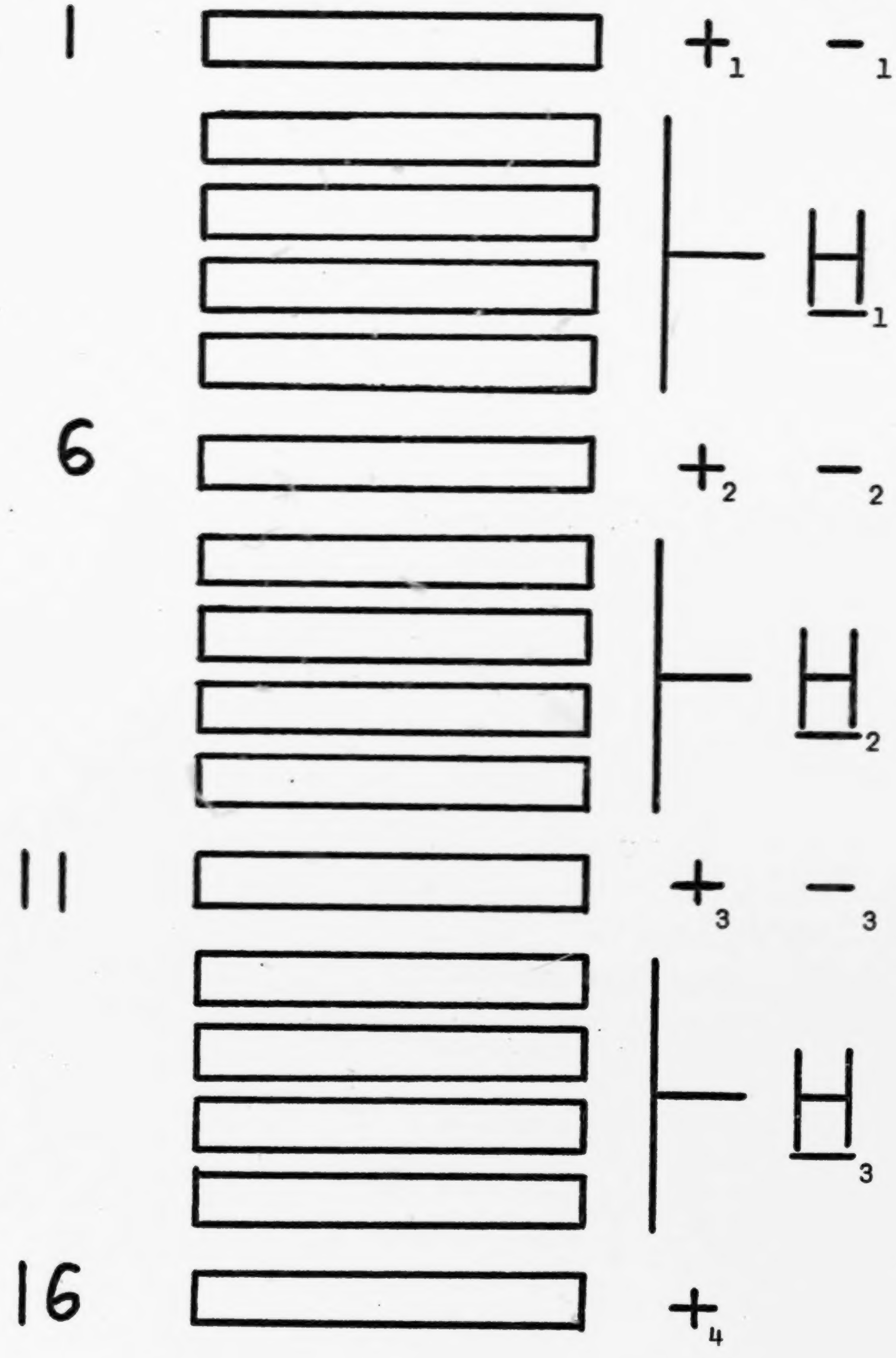
1
+1
−1
H1
6
+2
−2
H2
11
+3
−3
H3
16
+4

Figure 2. A schematic of the 16-trial problem showing the trials on which E said correct or wrong ($+_i$ or $-_i$) and the nonoutcome trials from which Hs were inferred.

problem there are exactly eight different stimulus pairs which can be presented. These may be grouped into two different sets of four pairs, the dimensions being perfectly counterbalanced within each set. Figure 1 shows such a set in which each level of every dimension appears exactly twice with each level of every other dimension. Such a counterbalanced set of stimulus pairs is described by Levine as internally orthogonal. The remaining set of four stimulus pairs may be produced by simply interchanging the positions of each stimulus. For the first pair, for example, the small white T would be placed on the left and the large black X on the right. This new set of four pairs also is internally orthogonal. Referring to one set as Set A and the interchanged set as Set B, Set A was used for all nonoutcome trials. That is, Trials 2-5 were composed of the four Set A stimuli, as were Trials 7-10, and Trials 12-15. The trial-to-trial order was different for each of the sequences. Set B was used for the remaining (outcome) trials. This arrangement has two virtues: The S never encounters a specific stimulus pair to which an outcome has previously been given, and the outcome stimulus pairs, as well as the nonoutcome sets, have the property of internal orthogonality.

The E said "correct" or "wrong" on Trials 1, 6, and 11 according to a prearranged schedule and regardless of the specific responses made by S. Each of the eight possible correct-wrong sequences which could occur on three trials was assigned to each of the first eight problems and again to each of the last eight problems. The sequences were assigned to different problems for each eight Ss in the different age groups, forming 8 x 8 Latin squares. Trial 16, the last trial of each problem, was treated separately: the E always said "correct" on this trial. Figure 2 summarizes the procedure.

Results

Since not all the data have been collected and analyzed, this section will discuss the implications of the results and the ways in which they will be analyzed.

Effects of Outcomes. The data yielded by the experiment will have bearing upon some common presumptions about H testing. As Levine (1963, 1966) points out, connotations of the notion of H testing are that when an H is confirmed (by "correct") it is retained for further testing, and when disconfirmed (by "wrong") is rejected for another H. Restle (1962) in his theoretical treatment of discrimination learning makes some specific assumptions with reference to this matter. He assumes that when S is told "correct," he keeps the H sampled; when he is told "wrong," he returns the H to the set and selects another H at random. A meaningful alternative to the latter assumption is that when S is told "wrong," he does not return the H to the set, at least not immediately, but instead samples from among other Hs. These presumed effects of "correct" and "wrong" may be evaluated directly by comparing the Hs before and after each outcome. Restle's theory implies that the probability will be 1.00 that two successive Hs (the first and the second or the second and the third) are the same when E says "correct" after the response on the intervening outcome trial. Data presented by Levine (1966) shows the actual probability to be .95 with college students as *Ss*. This finding indicates that Restle's assumption, that the effect of "correct" is to cause *S* to keep his *H*, is a reasonable one. Restle's position also implies that the probability will be .125 (one of eight) that two successive *Hs* are the same when *E* says "wrong" after the response on the intervening outcome trial. The alternative to Restle's assumption places this probability at .000. The observed probability (Levine, 1966) is .020 indicating that the latter assumption is more nearly correct: *S* (college student) seeks a new *H* without first replacing the old.

It is expected that the results of the proposed experiment will confirm Levine's conclusions with regard to college students. One also might expect that this simple behavior will be the same in younger *Ss*, although it is not inconceivable that developmental differences will be obtained. Sampling with replacement is a less efficient mode of problem solution than is sampling without replacement. Thus, a younger *S* might tend to return his *H* to the set and then resample at random.

Further evidence for a nonreplacement assumption, at least for college students, comes from Levine's finding that the rejection of an incorrect *H* lasts beyond one outcome trial. If "wrong" was said on the outcome trials following the first and second *H*, H_3 not only was different from H_2 but also was different from H_1; the probability that H_3 and H_1 were the same was found to be .04 by Levine. Thus, the rejection of an incorrect *H* lasted for several trials at the very least. Here is an aspect of *H* testing which one might reasonably expect to differ in *Ss* at different developmental levels. Rejection of the first *H* beyond one outcome trial is probably dependent upon *S*'s ability to remember preceding events. Short-term memory traditionally has been held to improve with age. Therefore, one might expect the observed probability that H_3 and H_1 are the same, given that "wrong" was said on both intervening outcome trials, to be near .125 (replacement condition) for younger *Ss* (fifth grade children). With increases in developmental level, the probability would be expected to decrease until the level is reached at which Levine's *Ss* were functioning.

Complexity of Hypothesis Testing. Restle's theory makes some very simple assumptions about the mechanics of hypothesis testing. In it, whenver *S* resamples, i.e., following "wrong," he does so after replacing his *H* in the set of *Hs*. The *S* never analyzes the information received on previously outcome trials, and he does not, therefore, reject *Hs* from consideration. In effect, the size of the *H* set from which *S* resamples is constant throughout the experiment. This results in an *S* who tests *Hs* rather inefficiently, at least to the extent that he does not utilize all of the information forthcoming from outcome trials.

Levine (1966) portrays the *S* as a somewhat more efficient analyzer of information. As an illustration of Levine's view, consider the selection of H_1 after the experimenter says "wrong" on the first outcome trial. By the nature of the stimuli, four *Hs* can be characterized as wrong and four as possibly right. If S were utilizing the information in the most efficient manner, then H_1 would always be one of the four Hs characterized as correct. Levine found the actual probability that H_1 was one of the four correct Hs to be .873. If this probability were 1.00, then the number of Hs from which S resampled, $N(H_1)$, would be a maximum of four; if it were .80, $N(H_1)$ would be a maximum of five (four correct Hs out of five). The pertinent assumption here is that the probability of choosing one of the four Hs still correct after the first outcome trial is equal to four divided by $N(H_1)$. Symbolically, $P(H_1+)=4/N(H_1)$. Since $P(H_1+)=.873$, $N(H_1)=4.6$. This value may be interpreted as the mean size of the functional H set when S resamples after E says "wrong" on Trial 1. Thus, H testing turns out to be a more efficient process that it is portrayed in Restle's theory.

The mean size of the functional H set after the experimenter says "wrong" on Trial 1, i.e., $N(H_1)$, is an aspect of H testing which is expected to differ as a function of developmental level. In the proposed experiment, $N(H_1)$ can vary from 8.0 (resampling with replacement) to 7.0 (resampling without replacement) to 4.0 (resampling from among possible correct Hs). Levine found that with college students $N(H_1)=$ 4.6. It is expected that the data yielded by the proposed experiment will show younger Ss to be less efficient in analyzing the information provided by "wrong" on Trial 1. Thus, $N(H_1)$ should be related inversely to developmental level: $N(H_1)$ should be larger for younger Ss.

Since college students utilize the information provided by the Trial 1 outcome in a fairly efficient manner, one naturally may wish to inquire next whether they utilize the information gained over several previous outcome trials when resampling. One might expect that with succeeding outcome trials S learns more and more Hs are incorrect and, thus, can reduce the size of the functional H set. When he resamples after "wrong", the later the wrong appears the smaller should $N(H_i)$ be. Levine's equation can be generalized to $P(H_i+)= N(H_i+)/N(H_i)$ where $N(H_i+)$ is the number of logically correct Hs after the ith outcome. With internally orthogonal stimuli, $N(H_i+)$ is four after one outcome, two after two outcomes, and one after three outcomes. $P(H_i+)$ is the obtained proportion of H_is which are logically correct.

Levine (1966) analyzed his data (college students) in a manner such that assessment was possible of the utilization of information gained over outcome trials. Figure 3 presents the value of $N(H_i)$ following a "wrong" at the ith trial. The obtained curve (Levine, 1966) is contrasted with two theoretical curves: (a) that to be obtained if no information from outcome trials were used in resampling (top curve) and (b) that to be obtained if Ss were perfect information retainers and analyzers (bottom curve). The Ss in fact showed a steady reduction in $N(H_i)$, although they were not perfect analyzers. Thus, the data indicate that S is not only rejecting the H manifested when "wrong" is said, but is rejecting Hs not manifested as well.

Insert Figure 3 about here

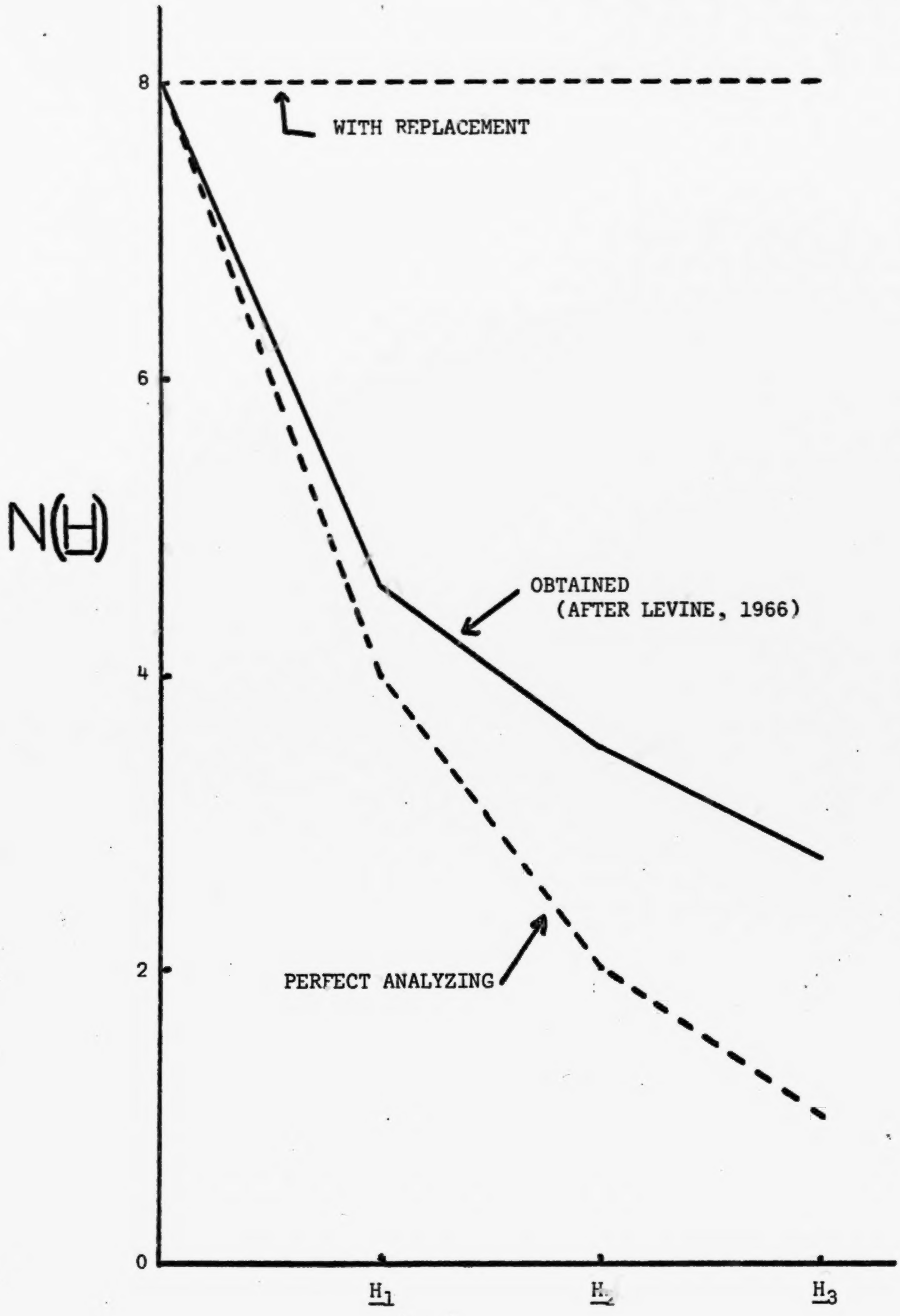

Figure 3. The size of the set, N (H_i), from which S is sampling $\underline{H}_i$ immediately following a wrong. (After Levine, 1966)

Here, one again has an aspect of H testing which might well be expected to differ as a function of developmental level. It seems likely that younger Ss will be less efficient than college students in analyzing and retaining the information provided by outcomes. Therefore, one would expect that the linear component of curves of the type shown in Figure 4 would be related to developmental level; younger Ss should show less steep functions. To put it another way, the size of the functional H set should not decrease as rapidly in younger Ss. The data yielded by the proposed experiment are expected to confirm this prediction.

The Effects of "Correct". The preceding discussion of the results forthcoming from studies like the proposed one has dealt only with the degree to which S retains and analyzes earlier information when he resamples, i.e., when E has just said "wrong." The proposed design also makes possible the evaluation of the effects of "correct." The assumption to this point has been that of Restle (1962), when E says "correct," S simply retains the same H he already has manifested. Levine's results indicate, however, that S is doing more than this. He apparently is attempting to store the information provided by the outcome and to combine it with that of prior outcome trials. Levine's results pertinent to this problem are portrayed in Figure 4. This figure shows the probability of selecting H_3 correctly, after a "wrong" on the third outcome trial, as a function of the number of "corrects" given during the first two outcome trials. Scrutiny of the graph shows clearly that the more often E said "correct" the more likely S was to select the only H consistent with the information provided by the previous outcome trials. The Ss in Levine's study not only used the positive outcomes to reject several incorrect Hs but, in addition, rejected more when they had been told "correct" than when they had been told "wrong."

Insert Figure 4 about here

The results of the proposed experiment also will be analyzed in the fashion just discussed. Whether or not the effects of "correct" and "wrong" will differ as a function of developmental level cannot be anticipated. There is perhaps no apriori reason to suspect that they will.

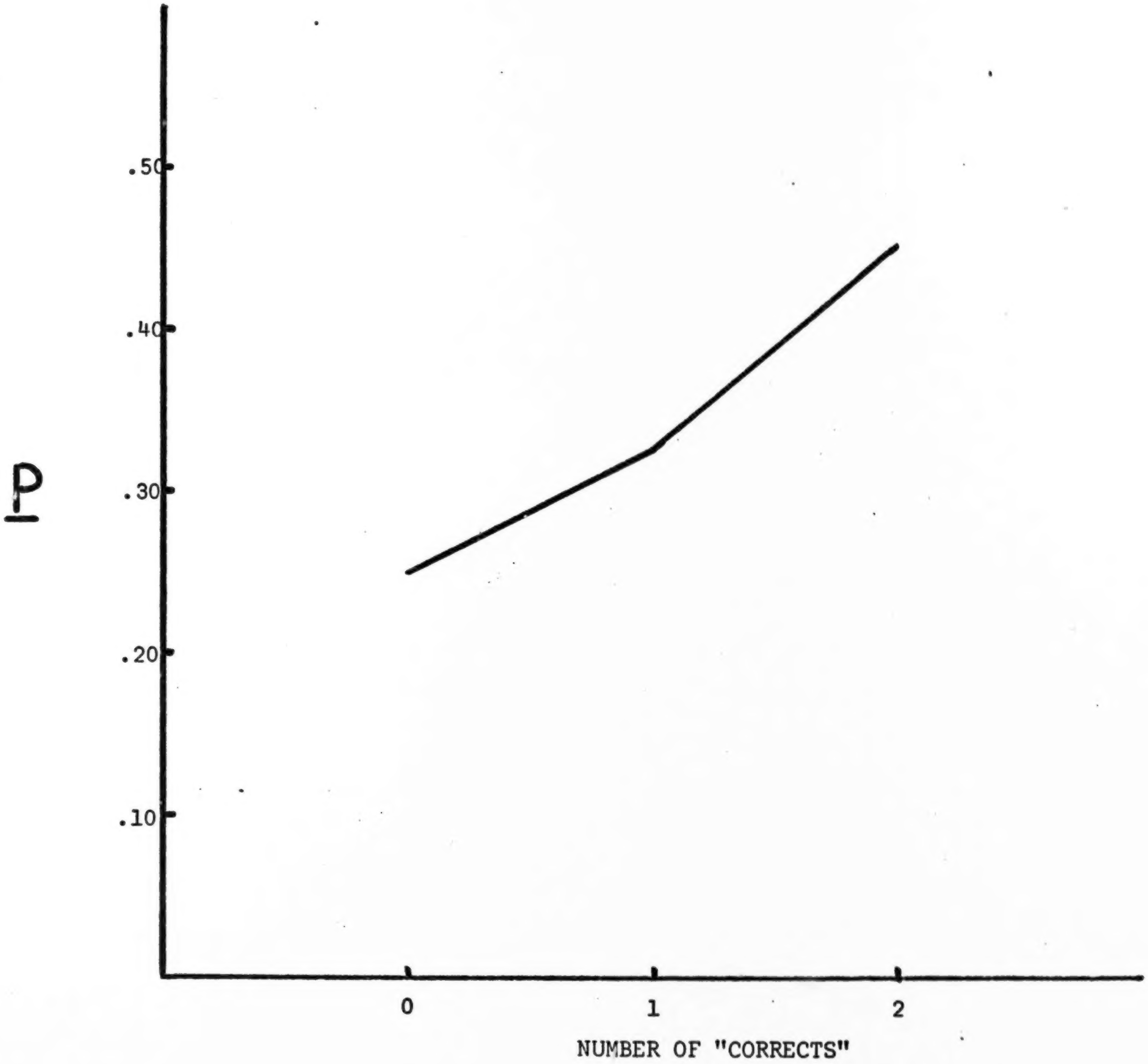

Figure 4. The probability that $\underline{H_3}$ is the correct $\underline{H}$ following wrong on the third outcome trial and with 0, 1, or 2 corrects on the first two outcome trials. (After Levine, 1966)

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Summary and Implications of the Research Program

The major focus of this research program has been an analysis of the problem-solving behavior of normal and mentally-retarded children. The problem-solving situation employed in all of the six experiments was two-choice, visual discrimination learning. Different experiments dealt with (a) the development of problem-solving behavior and (b) factors influencing such behavior. Although a variety of theoretical orientations were involved in the experiments described on the preceding pages, all experiments investigated the same research area, the study of the basic problem-solving process.

The following conclusions are warranted from the results of the experiments presented in this volume:

1. Experiments 1 and 2 really yielded no important results since the experimental manipulations had no effects. Stimulus similarity had no effect in these experiments upon the types of solutions (component, configurational or compound) adopted by mentally-retarded children on discrimination problems. Perhaps one could conclude from the results that it is not feasible to attempt the study of component, configurational, and compound responding by utilizing experimental designs in which each S receives all treatments.

2. Experiment 3 must be considered successful. The results of this experiment indicated a variety of conclusions. For mentally-retarded Ss with MAs ranging from 3 to 8 years, the following findings pertained: (a) Form cues predominated over color cues in the solving of discrimination problems. (b) Color-form compound cues also played a role in problem solution. (c) Avoidance of the negative compound was stronger than approach to the positive compound. (d) The strengths of these different cues to elicit the instrumental approach response apparently did not change with extended overtraining.

3. The results of Experiment 4 are perhaps the most important theoretically. These data show that intradimensional shifts and reversal shifts are learned faster than extradimensional shifts by kindergarten children only when the irrelevant shift dimension varies within trials. No learning differences were obtained when the irrelevant shift was constant within trials. These results call into question the conclusions of previous experiments in which the latter procedure was employed with kindergarten children. These children apparently are not at a point of transition from single-link to mediational functioning, but rather definitely are functioning in a mediational fashion.

4. The results of Experiment 5 show that intradimensional shifts are learned faster than extradimensional shifts by mentally-retarded Ss both when the irrelevant training dimension varies within trials and when it varies between trials and is constant within trials. The latter finding conflicts with the results of studies showing no intradimensional-extradimensional shift differences when the irrelevant training dimension

is constant both within and between trials. The results suggest then that retarded Ss learn to attend to compound dimensions under constant-irrelevant training conditions.

5. No conclusions are possible for Experiment 6 since the data are not collected entirely and since many analyses remain to be done. Preliminary inspection of the data of this experiment suggest that first-year college students and high-school sophomores behave very similarly with respect to hypothesis testing in the discrimination learning situation.

The results of these experiments have implications for the area of discrimination learning in general and especially for the development of problem-solving behavior. The theoretical implications of the experiments were discussed thoroughly in the portion of this report devoted to the respective studies and will not be reiterated here. While it is a long step from the laboratory to the classroom, it is through experiments of the type presented here that we shall gain a comprehensive body of knowledge about the basic learning process and its development. When sufficient information has been attained, we shall be able to apply laboratory principles to the classroom situation and, thus, facilitate the learning of children with various characteristics.